Total Maximum Daily Load Development to Address Bacteria and Benthic Impairments in the Spout Run Watershed, Clarke County, Virginia


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February 2010

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CHAPTER 1: EXECUTIVE SUMMARY

1.1. BACKGROUND

Spout Run is located in Clarke County southeast of Winchester, Virginia. Spout Run drains a land area of 13,710 acres. This area (the Spout Run watershed) is mostly covered by agricultural land (66%), with most of the remainder (26%) covered by forest. Spout Run flows east into the Shenandoah River, which flows into the Potomac River and ultimately to the Chesapeake Bay.

Definition:

Watershed – All of the land area that drains to a particular point or body of water.

1.2. THE PROBLEM

1.2.1. Too Much Bacteria

The Virginia Department of Environmental Quality (VADEQ) sets water quality standards or limits on the amount of pollution that is allowed in rivers and streams. To make sure that rivers are safe to swim and play in, VADEQ limits the amount of bacteria in the water. According to this standard, streams like Spout Run should not have more than 400 fecal coliforms or 235 *Escherichia coli* (*E. coli*) bacteria in every 100 milliliters (ml) of water. Fecal coliforms and *E. coli* are special types of bacteria that live in the guts of humans and animals. Finding these bacteria in the water means that human feces or manure is in the water and could make you sick.

Frequently Asked Question:

What's wrong with having bacteria in streams, isn't it natural? Finding fecal coliform and E. coli bacteria means that human feces or animal manure is in the water. Since feces carry many germs, there is a chance of getting sick if water gets in your mouth, nose, eyes, or an open wound.

Since 1991, VADEQ has been measuring the amount of bacteria in Spout Run. Twenty-seven percent of the time there has been more than the safe amount (Figure 1-1). Any stream that exceeds the safe amount more than 10.5% of the time is placed on Virginia's "Dirty Waters List" (or 303(d) List) and must have a clean-up plan. Spout Run was placed on this list in 1998, and

this report is the first step in developing a clean-up plan for Spout Run and its tributaries.
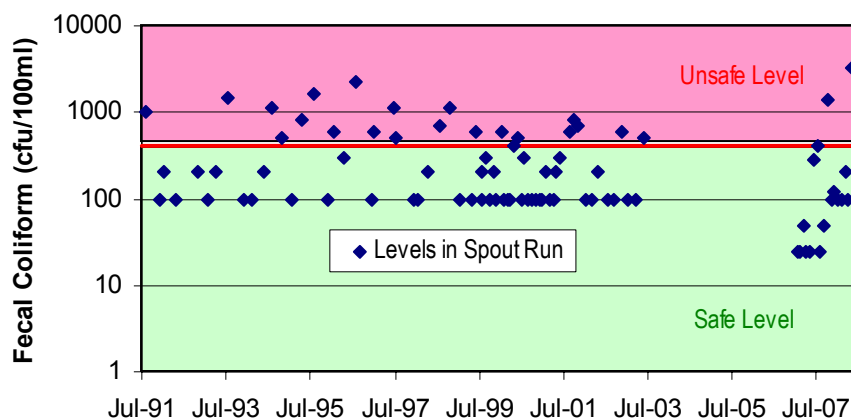
Figure 1-1. Bacteria (Fecal Coliform) Levels in Spout Run.

1.2.2. Too Much Sediment

In addition to having too much bacteria, Spout Run also fails to meet the state's standard for aquatic life. This means that the stream does not support a healthy and diverse community of bugs and fish. VADEQ conducted a study (called a stressor analysis) to figure out the reason for this impairment and determined that it was due to too much sediment entering the stream. Sediment that is washed off of the land surface or eroded from the stream banks accumulates in the stream. Excess sediment smothers certain bugs that live in the bottom of the stream and limits the diversity of aquatic life.

This report summarizes a study of bacteria and sediment in Spout Run and sets goals for a clean-up plan. The study is called a Total Maximum Daily Load (TMDL) Study, because it determines the maximum amount of bacteria and sediment that can get into Spout Run without harming the stream.

1.3. SOURCES OF BACTERIA AND SEDIMENT

Fecal coliforms come from the guts of humans and warm-blooded animals, so the sources of these bacteria in Spout Run must be from humans and animals living in the area that

drains to Spout Run (the watershed). In this study, VADEQ estimated the amount of bacteria coming from humans, pets, livestock (farm animals), and wildlife. The livestock that were considered in this study included beef cattle, horses, and sheep. Wildlife included deer, raccoon, beaver, muskrat, geese, ducks, and turkeys.

Some of the bacteria from these sources can get into Spout Run directly when a cow or wild animal defecates in the stream. Bacteria from humans can get into the stream directly from sewage treatment plants, or if houses have straight pipes right to the stream instead of a septic system. These straight pipes are illegal and VADEQ estimated that there may be as many as 18 along Spout Run and its tributaries. The Town of Boyce has a sewage treatment plant that discharges into Roseville Run, a tributary of Spout Run. Treatment plants typically do a good job of removing bacteria and are permitted by VADEQ to discharge into the stream as long as they keep bacteria levels below the safe amount.

While some sources can deposit bacteria directly into the stream, the majority of bacteria is deposited on the land and makes its way into Spout Run as runoff when it rains. The majority of bacteria from pets, livestock, and wildlife gets to the stream in this way. Bacteria from humans can also get to the stream this way if septic systems are failing and untreated sewage pools over the septic system drain field. Overall, 99.96% of the bacteria produced in the Spout Run watershed is first deposited on the land. Livestock accounts for most of those bacteria (98.6%), while wildlife accounts for 0.7%, pets account for 0.53%, and humans account for less than 0.15%.

Sediment that makes its way into Spout Run comes from either erosion of the land surface or erosion of the stream bank itself. The amount of erosion depends on many different factors including: when and how much it rains, the slope of the land, the type of soil, the land use, and the amount of vegetative cover on the land. To determine the amount of erosion in the watershed and the amount of sediment that enters Spout Run, VADEQ used a computer model.

1.4. COMPUTER MODELING

VADEQ used a computer model called the Loading Simulation Program C++ model (or LSPC) to track bacteria from the source, to the land, to the stream, and then downstream to the Shenandoah River. The amount of bacteria that ends up in the stream depends on the amount of bacteria that is deposited, how quickly it dies, how much and when it rains, and how much runoff is generated. The model considered these and other factors to predict the

amount of bacteria in Spout Run at any given time. To make sure that the predictions were accurate, the model was tested with real-world data. The model was used to predict bacteria levels in Spout Run and its tributaries from 1991 to 2008, and these predictions were compared to bacteria samples collected from the stream during that time period. The model was found to be accurate within about 5% of the measured data. Once the model passed this test, it could be used to make predictions about how bacteria levels in Spout Run might change if sources of bacteria were better controlled.

For predicting sediment loads, VADEQ used a computer model called the Generalized Watershed Loading Function model (or GWLF). This model considered the slope, soils, land cover, erodibility, and runoff to estimate the amount of soil eroded in the watershed and deposited in Spout Run. Similarly to the bacteria model, the sediment model was calibrated against real-world suspended sediment and flow measurements taken from the stream. The tested model could then be used to estimate the sediment reductions that would be needed to completely restore a healthy aquatic life to Spout Run.

1.5. CURRENT CONDITIONS

VADEQ used the tested computer models to figure out where the bacteria and sediment in Spout Run were currently coming from. Figure 1-2 shows the contributions of bacteria and sediment from various sources. The primary source of bacteria in Spout Run is from agricultural or farm runoff. Fifty-six percent comes from this source, while 23% comes

from cattle wading in the stream. Runoff from residential and urban areas accounts for 12%, and all other sources account for the remaining 9%.

Bacteria Sources

- Forest Runoff 0%
- Ag Runoff 56%
- Straight Pipes 7%
- Cattle DD 23%
- Wildlife DD 2%
- Point Sources 0%
- Res/Urban Runoff 12%

Sediment Sources

- Forest Runoff 1%
- Ag Runoff 36%
- Point Sources 0%
- Bank Erosion 60%
- Res/Urban Runoff 3%
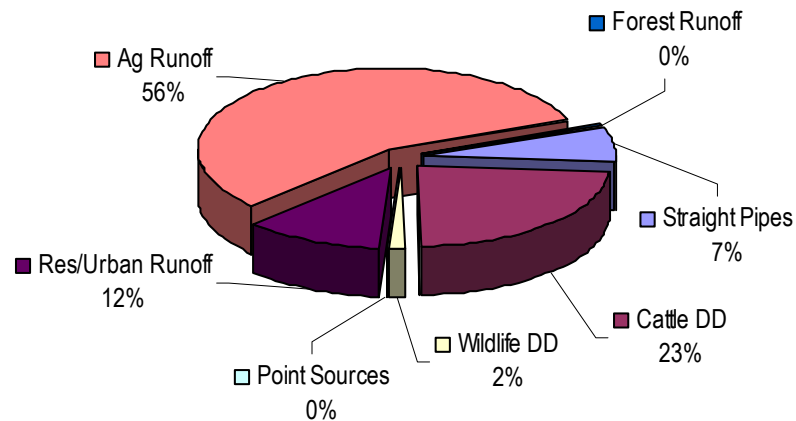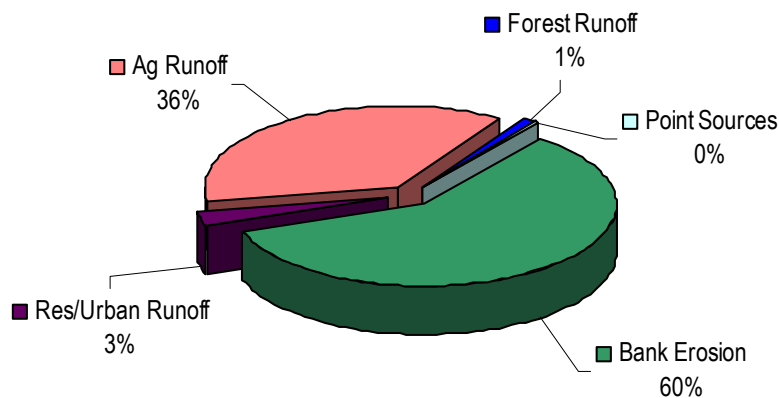
Figure 1-2. Where are the Bacteria and Sediment Currently Coming From?

Sources of sediment in Spout Run are much different from bacteria sources. Most of the sediment (60%) comes directly from erosion of the stream banks. Agricultural runoff is the second largest source, contributing 36%. The remaining sources contribute less than 4% combined.

1.6. FUTURE GOALS (THE TMDL)

After figuring out where the bacteria and sediment in Spout Run are currently coming from, the computer models were used to figure out how much bacteria and sediment

Definition:

TMDL – Total Maximum Daily Load. This is the amount of a pollutant that a stream can receive and still meet water quality standards. The term TMDL is also used more generally to describe the state's formal process for cleaning up polluted streams.

loads need to be reduced to clean up Spout Run and its tributaries. The ultimate goal is for Spout Run and its tributaries to never exceed the safe level of bacteria, and for Spout Run to have sediment levels that allow for diverse and abundant aquatic life. The reductions in bacteria and sediment loads needed to meet these goals are shown in Table 1-1 and Table 1-2.

Table 1-1. Reductions in Bacteria Needed to Clean Up Spout Run.

Source	Bacteria Reduction Needed (%)		
	Page Brook	Roseville Run	Spout Run
Straight Pipes	100%	100%	100%
Cattle DD	91%	83%	67%
Wildlife DD	0%	0%	0%
Permitted Point Sources	0%	0%	0%
Agricultural Runoff	50%	50%	67%
Residential/Urban Runoff	91%	83%	67%
Forest Runoff	0%	0%	0%

Definition:

Point Source – pollution that comes out of a pipe (like at a sewage treatment plant).
Non-point Source – pollution that does not come out of a pipe but comes generally from the landscape (usually as runoff).

In order to meet safe bacteria levels, various levels of reductions are needed from Spout Run and its two tributaries (Page Brook and Roseville Run). In Page Brook, 100% reductions are needed from straight pipes, 91% reductions are needed from cattle direct deposits (cattle wading in the stream) and residential/urban runoff, and 50% reductions are needed from agricultural runoff. In Roseville Run, 100% reductions are needed from straight pipes, 83% reductions are needed from cattle direct deposits (cattle wading in the stream) and residential/urban runoff, and 50% reductions are needed from agricultural runoff.   In Spout Run, 100% reductions are needed from straight pipes and 67%

reductions are needed from cattle direct deposits (cattle wading in the stream), residential/urban runoff, and agricultural runoff. If these reductions are made, the water quality standard for bacteria will be met and less than 1.41 x 10^{13} *E. coli* per year would enter Spout Run. This safe amount, known as the total maximum daily load (TMDL), is the maximum amount of bacteria that can enter Spout Run and still meet water quality standards. A small portion of this amount (5.22 x 10^{11} *E. coli* per year) is reserved for the permitted sewage treatment plant in the area (point sources), but most of the amount allows for bacteria from runoff and sources that do not come out of a pipe (nonpoint sources) (Table 1-3).

Table 1-2. Reductions in Sediment Needed to Clean Up Spout Run.

Source	% Reduction
Res/Urban	30%
Crop	30%
Pasture	30%
Degraded Riparian Pasture	67%
Forest	0%
Transitional	30%
Point Sources	0%
Bank Erosion	67%

In order to obtain healthy sediment levels in Spout Run, significant reductions are needed from several sediment sources. Sediment from bank erosion and degraded riparian pasture needs to be reduced by 67%. In addition, 30% reductions in sediment are needed from residential/urban areas, cropland, pasture, and transitional areas. If these reductions are made, less than 109 tonnes of sediment per year would enter Spout Run and healthy aquatic life should be restored. This represents the total maximum daily load of sediment for Spout Run (Table 1-4).

Table 1-3. Total Maximum Daily Load of Bacteria (*E. coli*) in Spout Run that Will Meet the Water Quality Standard.

Stream	Amount from Permitted Point Sources (WLA) (cfu/yr)	Amount from Nonpoint Sources (LA) (cfu/yr)	Margin of Safety	Total Maximum Daily Load (cfu/yr)
Page Brook	2.18E+11	5.31E+12	Implicit	5.53E+12
Roseville Run	3.05E+11	5.97E+12	Implicit	6.27E+12
Spout Run	5.22E+11	1.36E+13	Implicit	1.41E+13

Table 1-4. Total Maximum Daily Load of Sediment in Spout Run that Will Meet the Water Quality Standard.

Amount from Permitted Point Sources (WLA) (tonnes/yr)	Amount from Nonpoint Sources (LA) (tonnes/yr)	Margin of Safety (tonnes/yr)	Total Maximum Daily Load (tonnes/yr)
7.44	95.9	5.47	109

1.7. WHAT HAPPENS NEXT

VADEQ will ask for public comment on this report and then submit it to the U.S. Environmental Protection Agency (USEPA) for approval. This report sets the clean-up goals for Spout Run, but the next step is a clean-up plan (or Implementation Plan) that lays out how those goals will be reached. The clean-up plan will set intermediate goals and describe actions that should be taken to clean up Spout Run. Many of these actions are obvious and can be taken right now to improve the health and safety of Spout Run. Some of these actions are listed below:

- Fence out cattle from streams and provide alternative water sources

- Conduct stream bank restoration projects in areas where banks are actively eroding

- Find and fix straight pipes

- Leave a band of 35 – 100 ft along the stream natural so that it buffers or filters out bacteria and sediment from farm or residential land (a riparian buffer)

- Find and fix failing septic systems

- Pick up pet waste on residential and commercial land

These and other actions will be listed in the clean-up plan with associated costs and how much of each action it will take to meet the goals. The clean-up plan will also identify potential sources of money to help in the clean-up efforts. Most of this money will probably be available in the form of cost-share programs, which share the cost of improvements with the landowner. Please be aware that the state or federal government will not fix the problems with Spout Run. It is primarily the responsibility of individual landowners and local governments to take the actions necessary to improve Spout Run. The state agencies will help with developing the plan and finding money to support the plan, but actually making the improvements is up to those that live in the

Spout Run watershed. By increasing education and awareness of the problem, and by working together to each do our part, we can make the changes necessary to improve Spout Run.

VADEQ will continue to sample bacteria and aquatic life in Spout Run and monitor the progress of clean up. This sampling will let us know when the clean up has reached certain milestones listed in the plan. To begin moving towards these clean-up goals, VADEQ recommends that concerned citizens bond together and begin working with local governments, civic groups, soil and water conservation districts, and local health districts to increase education and awareness of the problem and promote those activities and programs that improve stream health.

> **Frequently Asked Question:**
>
> *How will the TMDL be implemented?* For point sources, TMDL reductions will be implemented through discharge permits. For nonpoint sources, TMDL reductions will be implemented through best management practices (BMPs). Landowners will be asked to voluntarily participate in state and federal programs that help defer the cost of BMP installation.

CHAPTER 2: INTRODUCTION

2.1. WATERSHED LOCATION AND DESCRIPTION

Spout Run is located in Clarke County, Virginia, approximately 5 miles southeast of Winchester, Virginia (Figure 2-1). The watershed is 13,710 acres in size and includes the Town of Boyce. Spout Run flows east and empties into the Shenandoah River, which drains to the Potomac River and ultimately to the Chesapeake Bay.
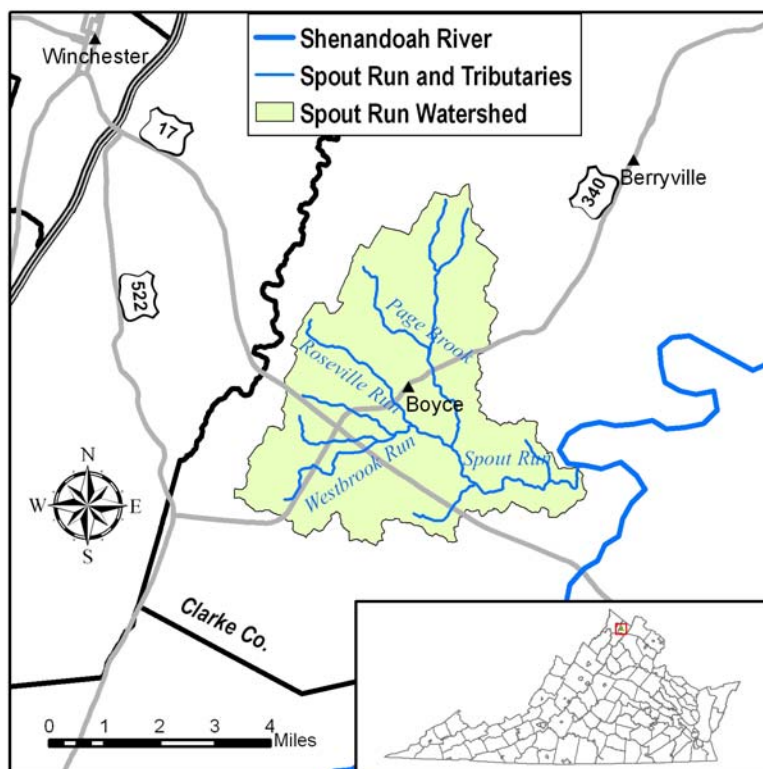
Figure 2-1. Location of Spout Run Watershed.

The Spout Run watershed (a portion of the designated VAV-B57R watershed) is located in the Ridge and Valley Level III Ecoregion (Woods *et al.*, 1999). The Ridge and Valley Level III Ecoregion is characterized by its generation from sedimentary rocks, including sandstone, shale, limestone, and dolomite. This ecoregion consists of alternating forested

ridges and agricultural valleys that are elongated and folded and faulted. Spout Run lies entirely within the agricultural valley, with the highest elevation being 682 ft. The land use in the watershed is primarily pasture and hay land (64%), with 26% forest.

2.2. DESIGNATED USES AND APPLICABLE WATER QUALITY STANDARDS

Virginia's Water Quality Standards (9 VAC 25-260-5) consist of designated uses established for water bodies in the Commonwealth, and water quality criteria set to protect those uses. Virginia's Water Quality Standards protect the public and environmental health of the Commonwealth and serve the purposes of the State Water Control Law (§62.1-44.2 *et seq.* of the Code of Virginia) and the federal Clean Water Act (33 USC §1251 *et seq.*).

2.2.1. Designation of Uses (9 VAC 25-260-10)

"A. All state waters, including wetlands, are designated for the following uses: recreational uses, e.g., swimming and boating; the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources, e.g., fish and shellfish" (State Water Control Board, 2006).

The above listed uses are designated for all state waters, including Spout Run. Spout Run and Page Brook (a tributary to Spout Run) do not support the recreational (swimming) designated use due to violations of the water quality criterion for bacteria. Spout Run also does not support the aquatic life designated use based on biological monitoring of the benthic macroinvertebrate community.

2.2.2. Bacteria Water Quality Criterion (9 VAC 25-260-170)

Because many human diseases and pathogens are transmitted through the feces, the presence of fecal matter in the water poses a human health risk. Swimming in fecally-contaminated water increases the risk of gastrointestinal illness and infection. To protect human health during primary contact recreation (e.g., swimming), the Commonwealth of Virginia has set limits on the amount of specific fecal bacteria in all state waters. The current bacteria criterion for freshwater (effective January 15, 2003) includes limits on

the amount of fecal coliform bacteria in water and the amount of *Escherichia coli* (*E. coli*) in water. Fecal coliforms are a group of bacteria that are found in the intestinal tract of warm-blooded animals. Even though most fecal coliforms are not pathogenic, their presence in water indicates contamination by fecal material. *E. coli* is a specific bacteria species within the group of fecal coliforms. Studies have shown that there is a stronger correlation between the concentration of *E. coli* and the incidence of gastrointestinal illness than there is with fecal coliform (USEPA, 1986), so the state is transitioning from a fecal coliform standard to an *E. coli* standard. All freshwaters are subject to the *E. coli* standard described below, and until June 30, 2008, the interim fecal coliform standard described below will also apply to any sampling stations with fewer than 12 *E. coli* samples.

The following bacteria criteria shall apply to all freshwaters in the Commonwealth in order to protect primary contact recreational uses (State Water Control Board, 2006):

Interim Fecal Coliform Criterion:

> *Fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 mL of water for two or more samples over a calendar month nor shall more than 10% of the total samples taken during any calendar month exceed 400 fecal coliform bacteria per 100 mL of water. This criterion shall not apply for a sampling station after the bacterial indicators described in subdivision 2 of this subsection [E. coli criterion] have a minimum of 12 data points or after June 30, 2008, whichever comes first.*

***Escherichia coli* Criterion**:

> *E. coli bacteria concentrations for freshwater shall not exceed a geometric mean of 126 counts per 100 mL for two or more samples taken during any calendar month and shall not exceed an instantaneous single sample maximum of 235 cfu/100mL.*

As a part of VADEQ's triennial review of water quality standards, revisions to the applicable bacteria standard were proposed in March 2008. The proposed revisions would remove the interim fecal coliform criterion and would revise the *E. coli* criterion to remove the instantaneous single sample maximum of 235 cfu/100ml. The revised criterion would consist of only the *E. coli* geometric mean criterion of 126 cfu/100ml. Since this revised standard was approved by the State Water Control Board in October

2008 and is awaiting USEPA approval, this revised standard will be considered the applicable water quality standard for the development of the Spout Run bacteria TMDL. In addition to meeting the geometric mean criterion, the TMDL will also be developed to meet the *E. coli* instantaneous target concentration of 235 cfu/100ml with a violation rate of less than 10.5%. Meeting this target will provide consistency with VADEQ assessment guidance (VADEQ, 2007).

2.2.3. General Standard (9VAC 25-260-20)

The following general standard protects the aquatic life use:

> *"A. All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life.*
>
> *Specific substances to be controlled include, but are not limited to: floating debris, oil scum, and other floating materials; toxic substances (including those which bioaccumulate); substances that produce color, tastes, turbidity, odors, or settle to form sludge deposits; and substances which nourish undesirable or nuisance aquatic plant life. Effluents which tend to raise the temperature of the receiving water will also be controlled"* (State Water Control Board, 2006).

VADEQ's biological monitoring program is used to evaluate compliance with the above standard. This program monitors the assemblage of benthic (bottom-dwelling) macro (large enough to see) invertebrates (insects, mollusks, crustaceans, and annelid worms) in streams to determine the biological health of the stream. Benthic macroinvertebrates are sensitive to water quality conditions, important links in aquatic food chains, major contributors to energy and nutrient cycling in aquatic habitats, relatively immobile, and easy to collect. These characteristics make them excellent indicators of aquatic health. Changes in water quality are reflected in changes in the structure and diversity of the benthic macroinvertebrate community.

Currently, VADEQ assesses the health of the benthic macroinvertebrate community using the Virginia Stream Condition Index (VSCI). This index was first developed by Tetra Tech (2003) and later validated by VADEQ (2006). The VSCI is a multimetric index based on 8 biomonitoring metrics. The index provides a score from 0-100, and this

score is compared to a statistically derived cutoff value based on the scores of regional reference sites.

2.3. 305(B)/303(D) WATER QUALITY ASSESSMENT

Under Section 305(b) of the Federal Clean Water Act, states are required to assess the quality of their water bodies in comparison to the applicable water quality standards. States are also required, under Section 303(d) of the Act, to prepare a list of water bodies that do not meet one or more water quality standards. This list is often called the "Impaired Waters List", or the "303(d) List", or the "TMDL List", or even the "Dirty Waters List". The Commonwealth of Virginia accomplishes both of these requirements through the publishing of an Integrated 305(b)/303(d) Water Quality Assessment Report ever two years. Each report assesses water quality by evaluating monitoring data from a six-year window. The assessment window for the most recent 2008 305(b)/303(d) Integrated Water Quality Assessment Report was from January 1, 2001 through December 31, 2006.

According to VADEQ's Water Quality Assessment Guidance Manual (VADEQ, 2007), water bodies are assessed as "fully supporting" the recreational designated use if 10.5% or fewer samples within the 6-year monitoring window violate the applicable bacteria standard. Water bodies are assessed as "not supporting" the recreational designated use (or "Impaired") if more than 10.5% of samples within the 6-year monitoring window exceed the applicable bacteria standard.

The degree of support for the aquatic life designated use is assessed based on the Virginia Stream Condition Index (VSCI) calculated from biological monitoring data. According to VADEQ's current Water Quality Assessment Guidance (VADEQ, 2007), streams with a calculated VSCI score ≥60 are assessed as "fully supporting" the aquatic life designated use. Streams with VSCI scores <60 are assessed as "impaired" or "not supporting" the aquatic life designated use.

Prior to the 2008 Water Quality Assessment, VADEQ used the USEPA Rapid Bioassessment Protocol (RBP) II (Barbour *et al.*, 1999) for assessing the aquatic life use.

This methodology compares a number of community structure and diversity metrics between a monitored site and a reference site. Reference sites are selected to represent a natural, unimpaired stream of approximately the same size and within the same ecoregion. Based on comparison to the reference site, the RBP produces a score for the monitored site and a classification of "non-impaired," "slightly impaired," "moderately impaired," or "severely impaired."   In Virginia, any stream segment with an overall rating of "moderately impaired" or "severely impaired" was considered impaired and not meeting the aquatic life designated use.

> **Interesting Fact:**
>
> Over 10,000 miles of Virginia streams and rivers were listed as impaired in the 2008 Water Quality Assessment Report.

2.3.1. Spout Run and Page Brook Impairment Listings

According to Virginia's 2008 305(b)/303(d) Integrated Report (VADEQ, 2008), Spout Run and Page Brook are listed as impaired (Figure 2-2). A 3.7 mile section of Spout Run from the confluence of Page Brook and Roseville Run to the confluence with the Shenandoah River is impaired for failure to support the recreational use (i.e., a bacterial impairment) and the aquatic life use (i.e., a benthic impairment). An 8.78 mile section of Page Brook from the headwaters to the confluence with Roseville Run is impaired for failure to support the recreational use (i.e., a bacterial impairment).

Spout Run was initially listed as impaired on Virginia's 1998 303(d) Impaired Waters List (VADEQ, 1998) due to violations of the general standard for aquatic life (Section 2.2.3) and the bacteria standard for recreational use (Section 2.2.2). The initial aquatic life (or benthic) impairment was based on an RBPII rating of moderately impaired. The initial bacterial impairment was based on 5 out of 19 (or 26% of) fecal coliform samples that violated the bacteria standard between July 1, 1992 and June 30, 1997.   Both impairments have remained throughout each biennial assessment, including the most recent 2008 assessment. During the 2008 assessment window (January 1, 2001 to December 31, 2006), VSCI scores ranged from 38 to 41, indicating impairment of the benthic macroinvertebrate community. During this same time period, 5 out of 18 (or 28%) of the fecal coliform samples collected from Spout Run exceeded the bacteria standard.

Page Brook was initially listed as impaired on Virginia's 2004 305(b)/303(d) Integrated Report (VADEQ, 2004) due to violations of the bacteria standard for recreational use. The initial bacterial impairment in Page Brook was based on 7 out of 9 (or 78% of) fecal coliform samples that violated the bacteria standard between January 1, 1998 and December 31, 2002. This impairment has remained throughout each biennial assessment, including the most recent 2008 assessment. During the 2008 assessment window (January 1, 2001 to December 31, 2006), 7 out of 12 (or 58%) of the fecal coliform samples collected from Page Brook exceeded the bacteria standard.
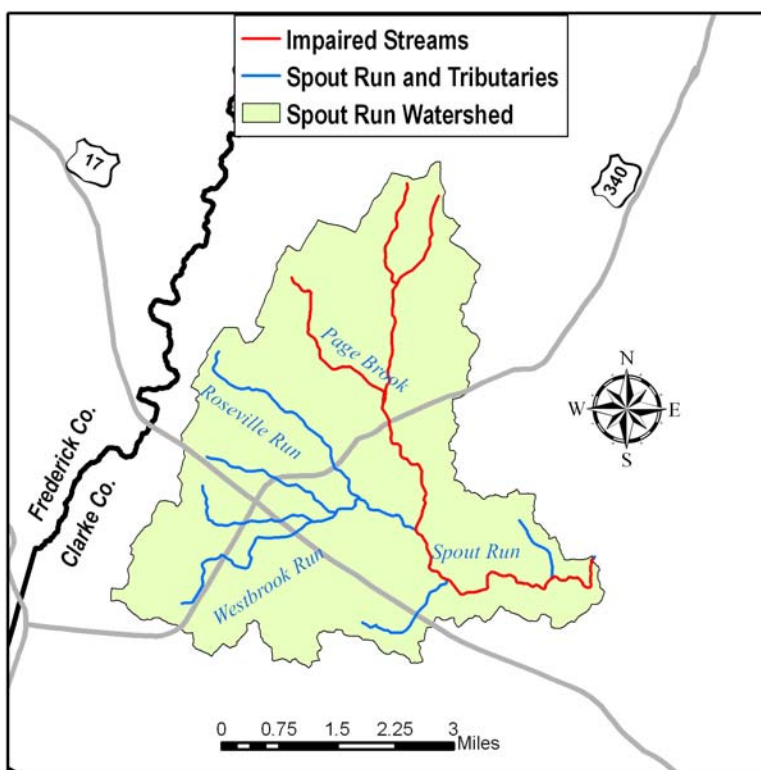
Figure 2-2. Impairments in the Spout Run Watershed.

2.4. TMDL DEVELOPMENT

Section 303(d) of the Federal Clean Water Act and the U.S. Environmental Protection Agency's (USEPA) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for water bodies

that fail to meet designated water quality standards and are placed on the state's Impaired Waters List. A TMDL reflects the total pollutant loading that a water body can receive and still meet water quality standards. A TMDL establishes the maximum allowable pollutant loading from both point and nonpoint sources for a water body, allocates the load among the pollutant contributors, and provides a framework for taking actions to restore water quality.

Due to the aquatic life impairment listed for Spout Run and the bacteria impairment listed for Spout Run and Page Brook, these segments were scheduled for TMDL development by 2010. This report establishes TMDLs to address the aquatic life impairment and bacterial impairments in these streams. While Roseville Run was not specifically identified as an impaired water in the 2008 water quality assessment report, water quality monitoring indicates that it is impaired and will be listed on the 2010 water quality assessment report. For this reason, a bacteria TMDL for Roseville Run is also established in this report.

The bacteria TMDLs for Spout Run, Page Brook, and Roseville Run were developed to meet the geometric mean *E. coli* standard of 126 cfu/100ml and meet the instantaneous target of 235 cfu/100ml with less than 10.5% exceedance rate. Because the majority of historic water quality monitoring data has been for fecal coliform rather than *E. coli*, the modeling was conducted with fecal coliform inputs, and then a translator equation was used to convert the output to *E. coli* (see Section 7.3.5).

To address the benthic impairment in Spout Run, a TMDL was developed for sediment. A stressor analysis determined that excess sediment was the primary stressor responsible for producing the benthic impairment (see Chapter 4).

CHAPTER 3: WATERSHED CHARACTERIZATION

3.1. WATER RESOURCES

3.1.1. Perennial Streams

The Spout Run watershed is located in Clarke County, Virginia (Figure 2-1). Spout Run is a 3.7-mile limestone-dominated stream in a low gradient agricultural plain. Spout Run is formed by the confluence of Page Brook and Roseville Run and empties into the Shenandoah River. The only other named tributary in the basin is Westbrook Run, which joins Roseville Run prior to the confluence with Page Brook. In total, there are 14 miles of perennial streams in the Spout Run watershed (Figure 3-1).

3.1.2. Springs

In addition to perennial streams, springs play a large role in the hydrology and water quality of Spout Run. Numerous springs have been identified in the watershed (Figure 3-1), and many have been monitored for flow and water quality (Table 3-1). These springs have a significant influence on Spout Run by affecting flow, temperature, and water chemistry. The springs produce a strong and consistent baseflow for Spout Run that is greater than anticipated based on drainage area alone. For instance, the drainage area of Spout Run is less than half of the size of the nearby Upper Opequon Creek watershed, yet Spout Run has a higher long term median flow than the Opequon (11.0 cfs compared to 9.3 cfs). The springs also allow Spout Run to maintain a cool water temperature despite a lack of tree cover and shading throughout much of the basin. In continuous temperature monitoring from October 2006 through August 2008, the maximum water temperature was only 19.9°C. Lastly, the springs influence water chemistry significantly. Because of the limestone origin of these springs, Spout Run has very high conductivity, alkalinity, total dissolved solids, and hardness. Dissolved ions in Spout Run are so high that salts such as calcium carbonate can precipitate from the water column forming marl, a rock coating of calcium carbonate-rich clay.
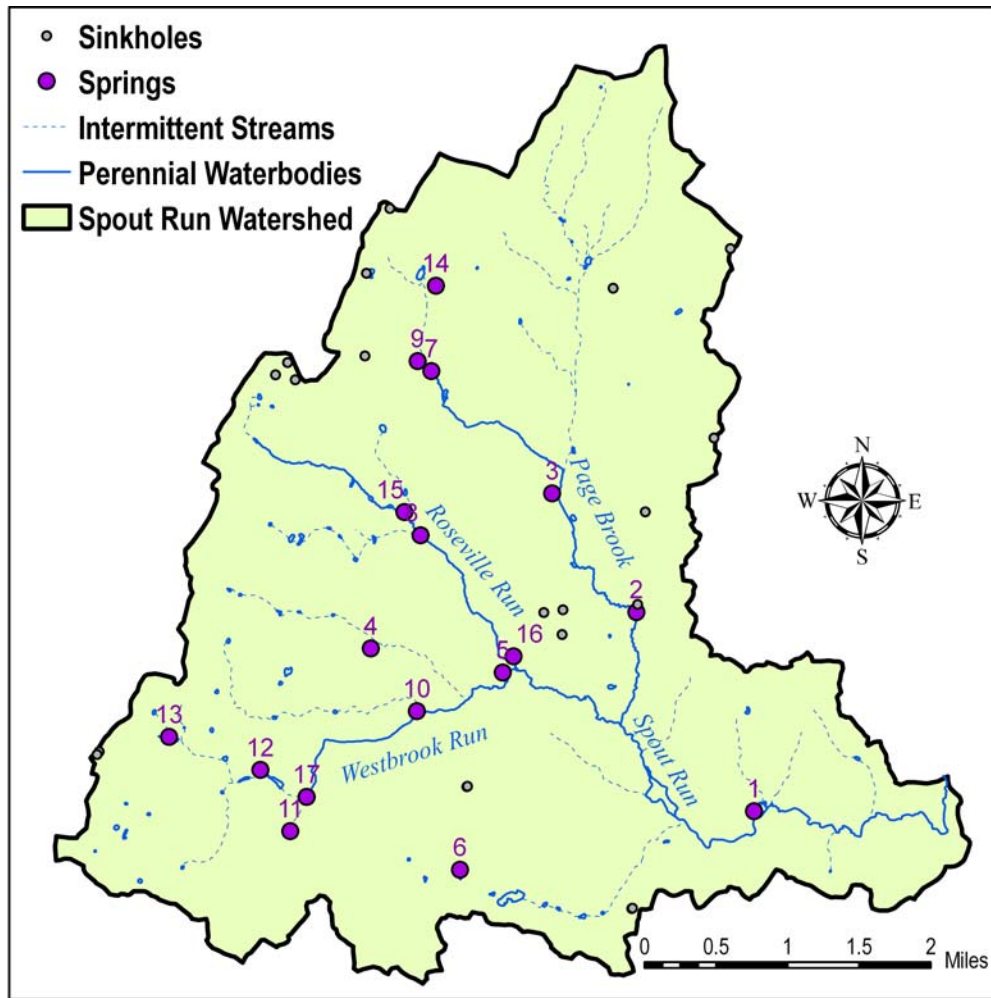
Figure 3-1. Spout Run Tributaries and Springs.

3.1.3. Stream Flow

The U.S. Geological Survey (USGS) currently operates a flow monitoring gage on Spout Run at Rt. 621 near Millwood, Virginia (Station 01636316). This station has only been in operation since August 2002. For the 5 complete years of record, the annual mean flow averaged 25.12 cfs. The year of highest annual mean flow was 2003, when flow averaged 37.2 cfs. The year of lowest annual mean flow was 2006, when flow averaged 15.5 cfs.

Stream flows in Spout Run are generally highest in the spring and decrease through the summer and fall (Figure 3-2). The average monthly stream flow peaks in March at 37 cfs

and decreases to a low of 15 cfs in August. Figure 3-3 shows the daily stream flow for Spout Run since 2002. Daily flows have ranged from 5.2 cfs in September 2002 to 450 cfs in December 2003.

Table 3-1. Springs Located in the Spout Run Watershed.

Map ID	Spring Name	Latitude	Longitude	Measured Ranges				
				Flow (gpm)	Temp. (°C)	Conductiv-ity (uS/cm)	pH	DO (mg/L)
1	Carter Hall Spring	39.06834	-78.02811	1894 - 5492	12.2 - 14.4	493 - 569	6.6 - 8.1	
2	Prospect Hill Spring	39.08865	-78.04298	691 - 710	11.5 - 12.8	555 - 575	6.7 - 7.3	6.2
3	Huntingdon Spring	39.10080	-78.05367		12.7	592	6.9	3.0
4	Unnamed	39.08539	-78.07751					
5	Saratoga Spring #1	39.08276	-78.06043	300	12.3	604	6.8	2.6
6	Blandy Farm - Rattlesnake Spring	39.06288	-78.06639					
7	Unnamed	39.11337	-78.06910					
8	Butler Spring	39.09677	-78.07083					
9	Pagebrook Spring	39.11438	-78.07086	200	13.6	533	6.3	0.9
10	Strosnider Spring	39.07900	-78.07166					
11	Fritt's Spring	39.06705	-78.08833					
12	Unnamed	39.07328	-78.09209					
13	Westbrook Spring	39.07677	-78.10389					
14	Unnamed	39.12200	-78.06835					
15	Lewis Spring	39.09914	-78.07289					
16	Saratoga Spring #2	39.08439	-78.05901					
17	Unknown	39.07048	-78.08615					
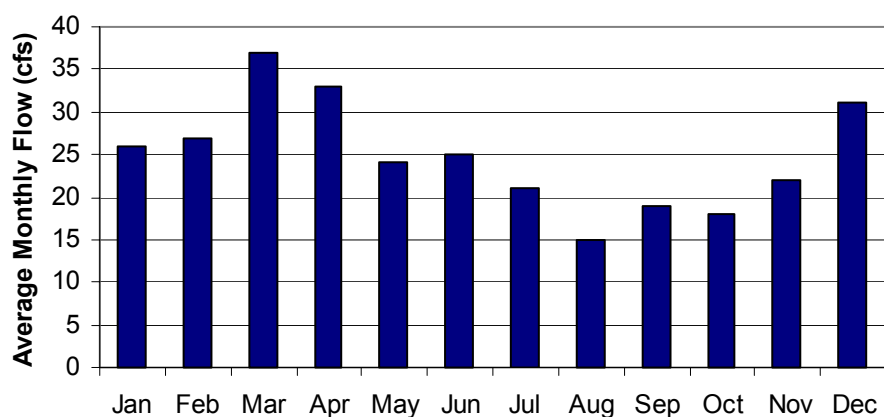
Figure 3-2. Average Monthly Stream Flow in Spout Run.
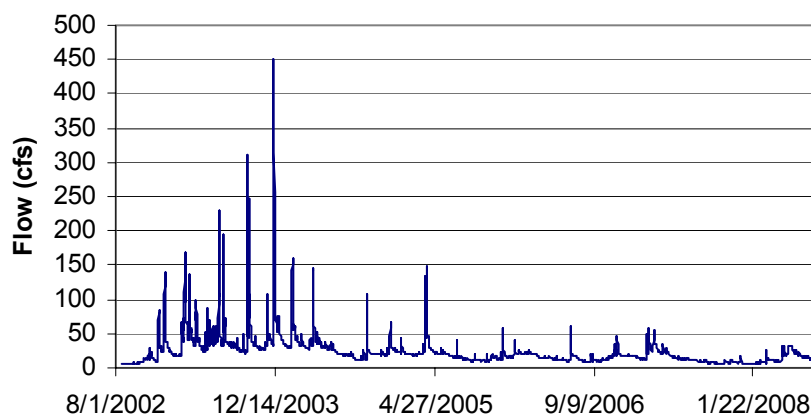
Figure 3-3. Daily Stream Flow in Spout Run.

3.2. SUB-WATERSHED DELINEATION

To assist in modeling the hydrology and water quality of Spout Run, the watershed was divided into 20 sub-watersheds based on the network of drainage areas and the location of monitoring stations (Figure 3-4). The sub-watersheds averaged 686 acres a piece and ranged in size from 56 acres (sub-watershed 20) to 1723 acres (sub-watershed 9).
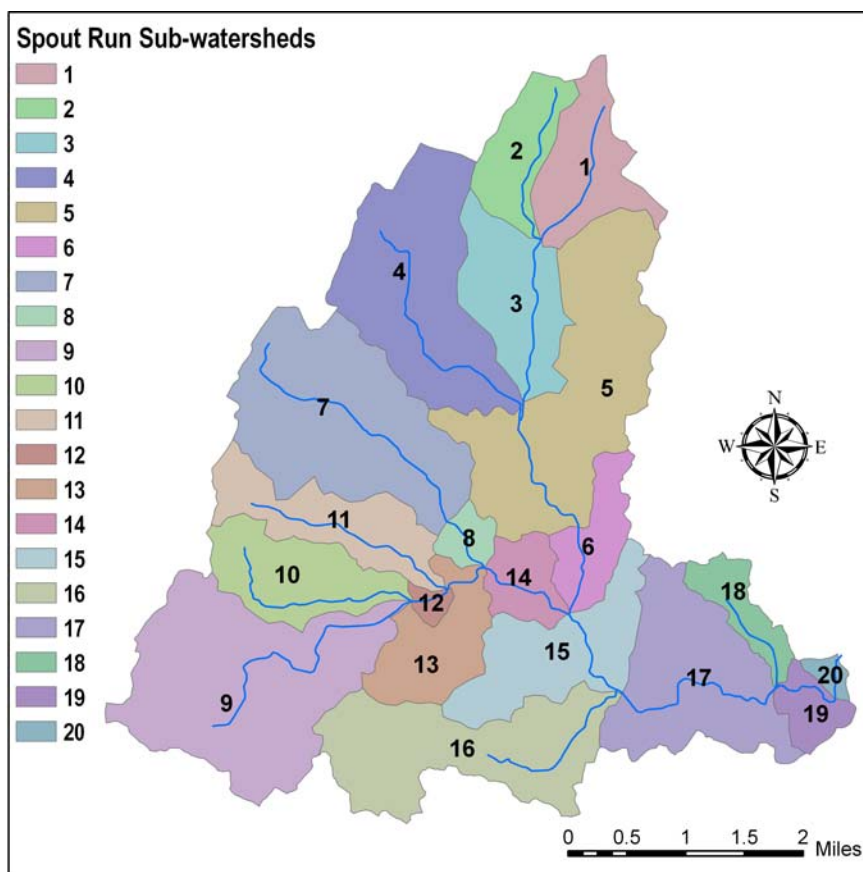
Figure 3-4. Sub-watershed Delineation in the Spout Run Watershed.

3.3. ECOREGION

The Spout Run watershed is located in the Ridge and Valley Level III Ecoregion (Woods *et al.*, 1999). The Ridge and Valley Level III Ecoregion is characterized by its generation from sedimentary rocks, including sandstone, shale, limestone, and dolomite. This ecoregion consists of alternating forested ridges and agricultural valleys that are elongated and folded and faulted. Level IV Ecoregions within the area include the Northern Shale Valleys to the west, the Northern Sedimentary and Metasedimentary Ridges to the east, and the Northern Limestone/Dolomite Valley, which encompasses the entire Spout Run watershed (Figure 3-5).

The Northern Limestone/Dolomite Valley Level IV Ecoregion is characterized by broad, level to undulating, fertile valleys that are extensively farmed, and contain scattered woodlands on steeper slopes. Sinkholes, underground streams, and other karst features

have developed on the underlying limestone and dolomite. Streams tend to flow year-round and have gentle slopes.
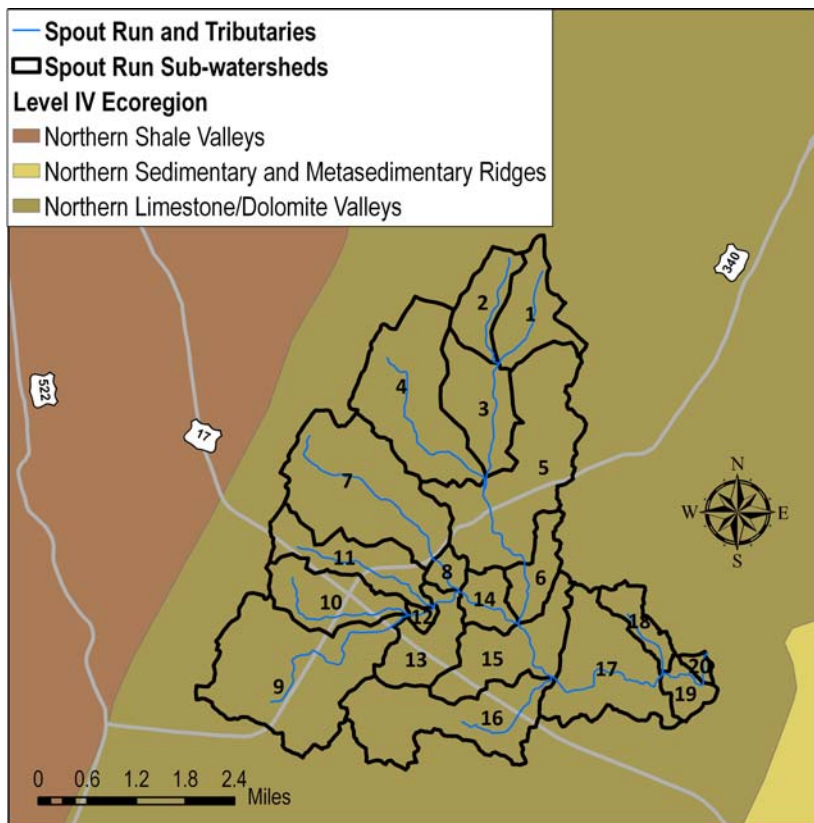
Figure 3-5. Level IV Ecoregions in the Spout Run Watershed.

3.4. SOILS AND GEOLOGY

Soils data for the Spout Run watershed were obtained from the U.S. General Soil Map (STATSGO) database (NRCS, 2006) and are shown in Figure 3-6. The Spout Run watershed is characterized by three soil types. The western 48% of the watershed (primarily west of Rt. 340) consists of the Carbo-Chilhowie-Frederick series soils (VA002). These soils are moderately deep to very deep and are well drained. They are formed in material weathered primarily from limestone with small amounts of interbedded sandstone, siltstone, and shale. Permeability in these soils is moderate to slow. These soils are in hydrologic soil group C or B.

The central 49% of the watershed consists of Hagerstown-Duffield-Clarksburg soils (VA069). These soils consist of deep and very deep, well drained soils formed in residuum of hard gray limestone. Rock outcrops are common in this soil type, and permeability is moderate. These soils are in hydrologic soil group C.

A small portion (3%) of the watershed near the mouth of Spout Run consists of Moomaw-Jefferson-Alonzville soils (VA004). These soils consist of deep and very deep, well drained soils formed in acid sandstone, quartzite, shales, and siltstones. These soils are common on stream terraces. Permeability is moderate to moderately rapid in Jefferson and Alonzville series but is slow to moderately slow in Moomaw series due to a fragipan at 15 to 30 inches in depth. Rock outcrops are common in this soil type, and permeability is moderate. These soils are in hydrologic soil group B/C.
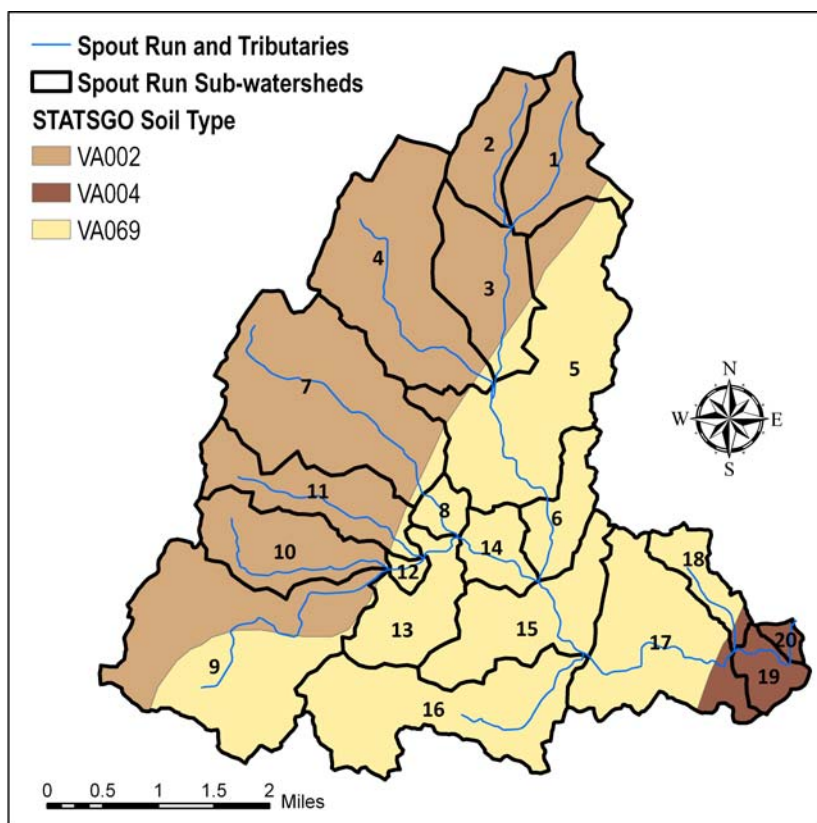
Figure 3-6. Soil Types in the Spout Run Watershed.

3.5. ELEVATION

The Spout Run watershed has an average elevation of 181 m (or 594 ft) above sea level. The watershed is relatively flat, varying only 89 m (or 292 ft) from its highest point at 208 m to its lowest point of 119 m above sea level at the mouth of Spout Run (Figure 3-7). This modest change in elevation leads to a rather gradual stream slope for Spout Run and its tributaries. Page Brook averages a slope of 0.45%, Roseville Run averages 0.61%, and Spout Run averages 0.65% in slope.
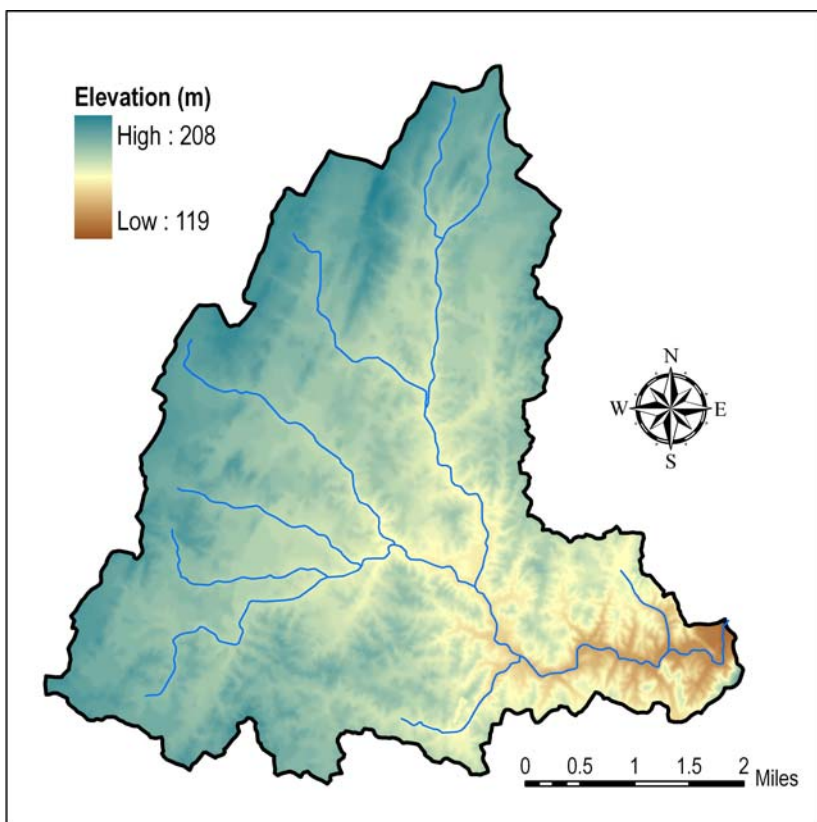
Figure 3-7. Elevation and Relief in the Spout Run Watershed.

3.6. CLIMATE

Climate data from the Winchester weather station were used to characterize climate in the Spout Run watershed (SERCC, 2006). The average annual precipitation at this location

from 1948-2007 was 38.53 inches, with average monthly precipitation varying from 2.39 inches in January to 3.92 inches in June. Average annual snowfall is 22.4 inches, occurring in November through April, with 57% occurring in January and February. The average annual minimum and maximum temperatures are 42.3 and 65.1°F, respectively. The average monthly maximum temperature of 86.6°F occurs in July, and the average monthly minimum temperature of 22.4°F occurs in January.

3.7. LAND COVER

Land cover data for the Spout Run watershed was obtained from the 2005 Virginia Department of Forestry's (VADOF) Virginia Land Use Dataset (VADOF, 2005). This database was developed from satellite imagery captured from 2002 to 2005 and is currently the most up-to-date land cover data available for the Spout Run watershed. Figure 3-8 shows the land cover in the Spout Run watershed. This watershed consists primarily of agricultural land (66%), with most of the remainder forested (26%). Impervious areas comprise about 2.4% of the watershed, and residential areas contribute 5.6%. These impervious and residential areas are primarily centered around the Town of Boyce and major roadways including Rt. 340, Rt. 17, Rt. 255, and old Rt. 50 (now 723).

Table 3-2 shows the acreage and percentage of each land cover type in the Spout Run watershed. These 14 land cover categories were further summarized into 6 aggregated land cover categories (plus open water) to simplify modeling efforts. Section 7.2.2 describes how land cover data were further modified to provide an accurate land use data set for modeling the watershed.
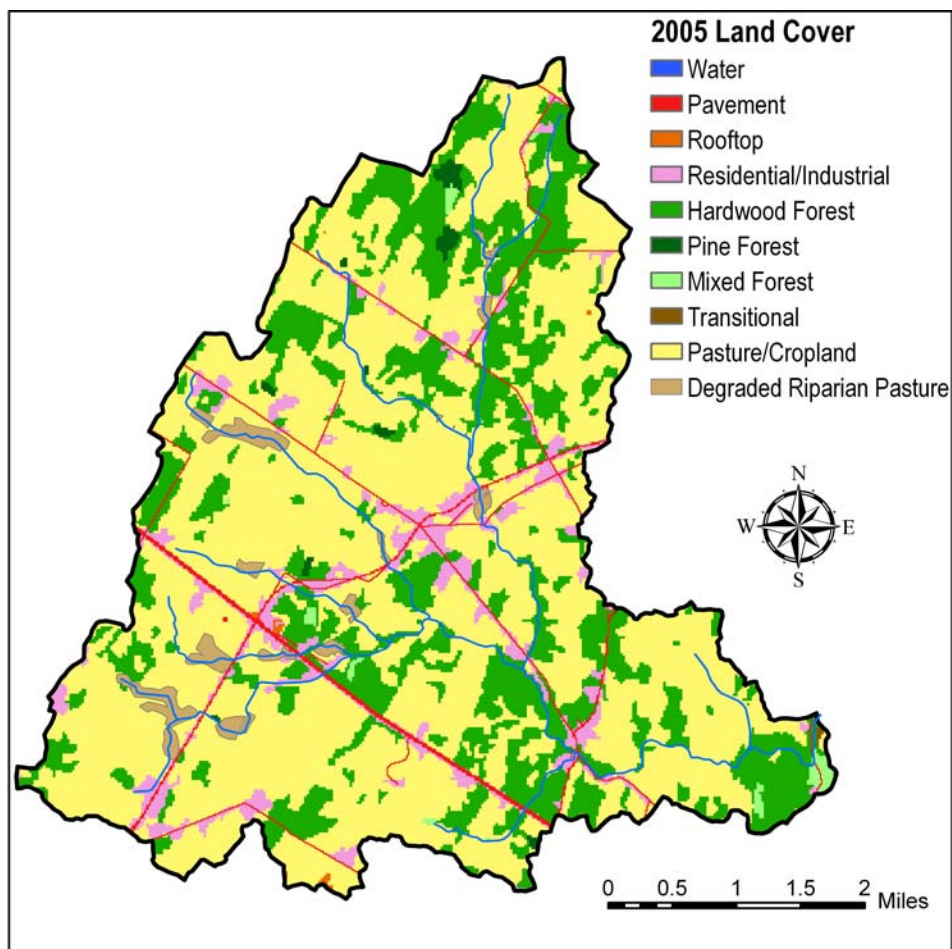
Figure 3-8. Land Cover in the Spout Run Watershed.

Table 3-2. Land Cover in the Spout Run Watershed.

Land Cover	Acres	%	Aggregated Land Cover	Acres	%
Water	<1	0.0%	Water	<1	0.0%
Pavement	314	2.3%	Urban/Transportation	326	2.4%
Rooftop	12	0.1%			
Residential/Industrial	771	5.6%	Residential	771	5.6%
Natural Barren	0	0.0%	Transitional	3	0.0%
Mine/Quarry	0	0.0%			
Bare Soil	0	0.0%			
Forest Harvest	3	0.0%			
Hardwood Forest	3420	25.0%	Forest	3562	26.0%
Pine Forest	73	0.5%			
Mixed Forest	69	0.5%			
Grassland	0	0.0%	Crop/Pasture/Hay	9049	66.0%
Crop/Pasture/Hay	9049	66.0%			
Salt Marsh	0	0.0%	Wetland	0	0.0%
Total	**13711**	**100.0%**	**Total**	**13711**	**100.0%**

3.8. BACTERIA MONITORING DATA

VADEQ has been monitoring fecal coliform in Spout Run since 1991. Since that time, VADEQ has collected 86 fecal coliform samples from the primary monitoring station (1BSPR000.40) on Rt. 621 near the mouth (Figure 3-9). Fecal coliform data have also been collected from monitoring stations on the main tributaries to Spout Run (Page Brook and Roseville Run). Table 3-3 summarizes fecal coliform data from each station. Fecal coliform concentrations are typically higher on Page Brook than on Roseville Run or Spout Run. On Page Brook, 60% of samples have violated the bacteria water quality standard (400 cfu/100ml), compared to only 28% and 27% on Roseville Run and Spout Run, respectively. Median and geometric mean concentrations of fecal coliforms are also higher on Page Brook than Roseville Run or Spout Run. The geometric mean of fecal coliform concentrations on Page Brook exceeds the geometric mean standard of 200 cfu/100ml, while the geometric means on Roseville Run and Spout Run are just below the standard. Figure 3-10 shows all of the measured fecal coliform concentrations in the Spout Run watershed since 1991. Those points above the red line indicate samples that exceed the instantaneous water quality standard of 400 cfu/100ml.
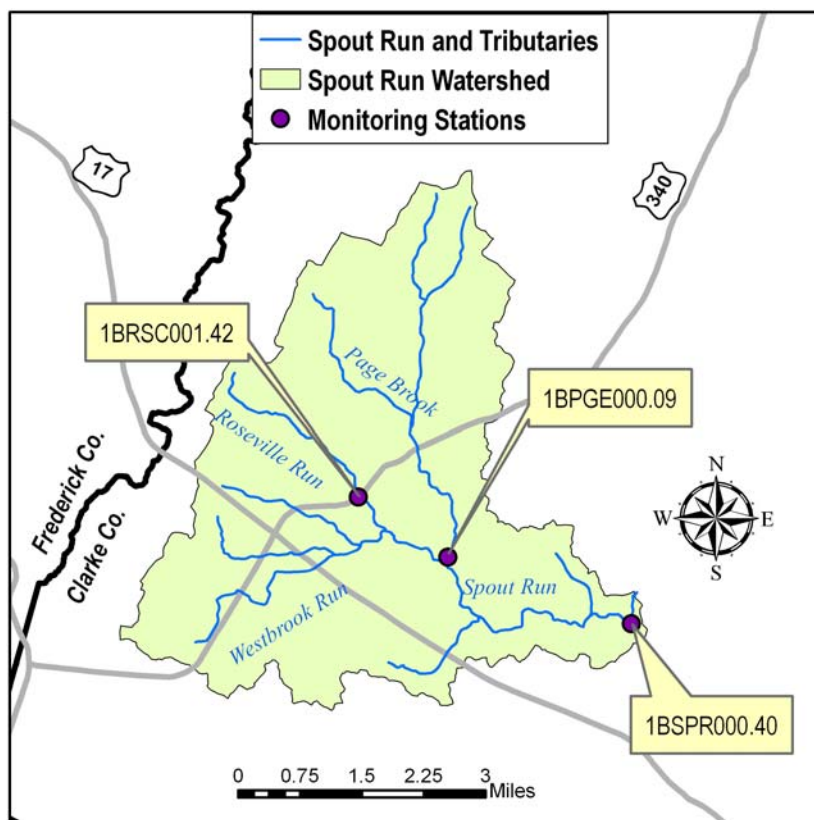
Figure 3-9. Monitoring Stations in the Spout Run Watershed.

Table 3-3. Summary Statistics for Fecal Coliform Data Collected from Spout Run and Tributaries.

	1BPGE000.09	1BRSC001.42	1BSPR000.40
Sampling Dates	8/28/01 - 6/10/08	1/29/07 - 6/10/08	7/30/91 - 6/10/08
Number of Samples	30	18	86
Min	<25	<25	<25
Max	2600	>16000	3200
Average	726	1228	365
Median	590	88	100
Geometric Mean	391	147	194
Violation Rate	60%	28%	27%
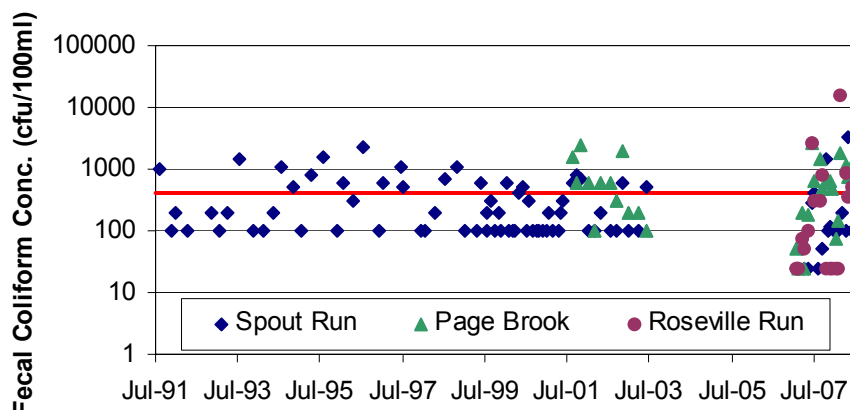
Figure 3-10. Fecal Coliform Levels in the Spout Run Watershed.

In 2007, VADEQ began monitoring *E. coli* as well as fecal coliform in the Spout Run watershed. Table 3-4 summarizes *E. coli* data from each monitoring station. Even with fewer data, *E. coli* results were similar to fecal coliform results. The greatest levels of contamination were observed in Page Brook, followed by Roseville Run, followed by Spout Run. Page Brook exceeded the instantaneous *E. coli* standard 61% of the time, while Roseville Run exceeded the standard 39% of the time, and Spout Run exceeded the standard 27% of the time. Figure 3-11 shows the measured *E. coli* concentrations in the Spout Run watershed since 2007.

Table 3-4. Summary Statistics for *E. coli* Data Collected from the Spout Run Watershed.

	1BPGE000.09	1BRSC001.42	1BSPR000.40
Sampling Dates	1/29/07 - 6/10/08	1/29/07 - 6/10/08	1/29/07 - 6/10/08
Number of Samples	18	18	15
Min	<25	<25	<25
Max	>2000	>2000	1000
Average	634	432	179
Median	475	150	100
Geometric Mean	298	149	90
Violation Rate	61%	39%	27%
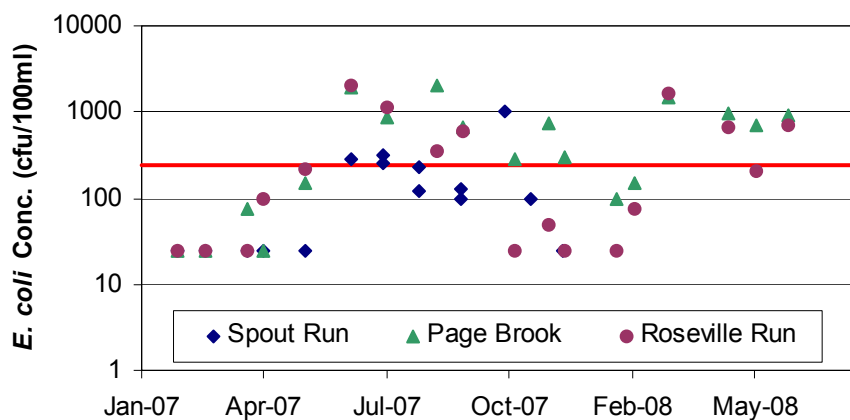
Figure 3-11. *E. coli* **Levels in the Spout Run Watershed.**

3.8.1. Temporal Variation

Fecal coliform has been sampled in Spout Run since 1991, so sufficient data exist to evaluate the trends in fecal coliform levels over time. Table 3-5 summarizes fecal coliform data within 5-year windows from 1991 to present. Within each successive period, violation rates and geometric mean fecal coliform levels have decreased. Violation rates have decreased from 31% in 1991-1995 to 11% in 2006-2008. The geometric mean of fecal coliform levels has dropped by more than half, from 245 in 1991-1995 to 106 in 2006-2008. These trends are further demonstrated in Figure 3-12.

Table 3-5. Fecal Coliform Violation Rates and Geometric Means Since 1991.

	1991-1995	1996-2000	2001-2005	2006-2008
Number of Samples	16	33	18	18
Number of Violations	5	10	5	2
% Violation Rate	31%	30%	28%	11%
Geometric Mean	245	227	199	106
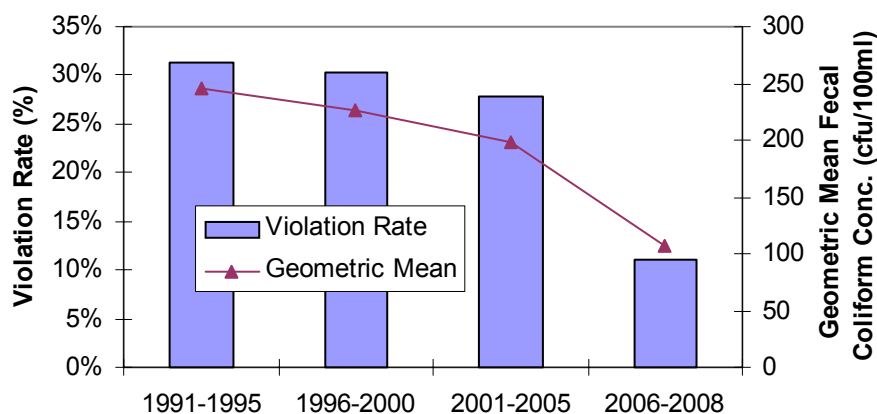
Figure 3-12. Trends in Fecal Coliform Levels in Spout Run.

3.8.2. Seasonal Variation

Fecal coliform data from Spout Run were analyzed for seasonal trends by plotting the violation rates for each month (Figure 3-13). A moderately strong seasonal trend was observed. Violation rates were higher in the summer and fall months (June – November) than in the winter and spring months (December – May). Violation rates reached as high as 67% in June and 64% in July, while violation rates in December – May were all below 25%. This seasonal trend may be a result of decreased flow in the summer and fall months or it may be a result of seasonal bacteria sources. Some bacteria sources such as direct deposit from livestock or manure applications are seasonal. Bacteria from these sources are more prevalent in the warmer months because cattle wade in streams more frequently and manure applications are typically made during the growing season. Other sources such as wildlife, pets, septic systems, and point sources are more constant throughout the year and would not explain the observed seasonal patterns.
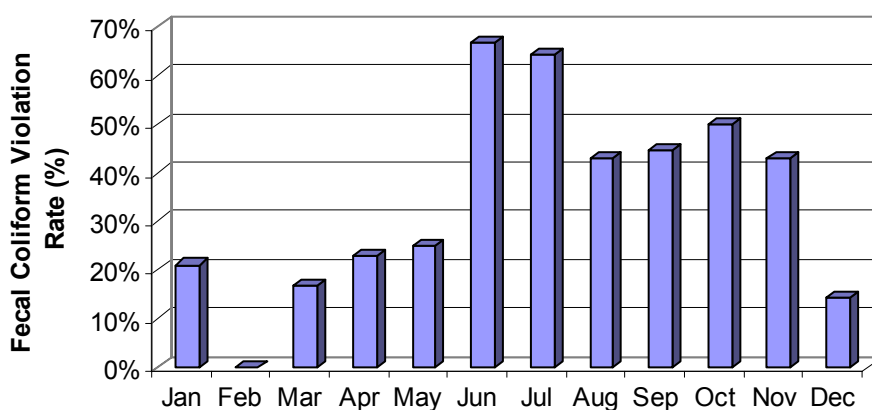
Figure 3-13. Monthly Violation Rate of Fecal Coliform Standard in Spout Run.

3.8.3. Variation with Flow

Fecal coliform levels were compared across Spout Run flow regimes to determine if violations occurred more frequently under specific flow conditions. Figure 3-14 plots fecal coliform levels in Spout Run against the flow frequency curve. Fecal coliform samples were collected under all flow regimes from very low flow to very high flow. Violations of the fecal coliform standard were observed under all flow regimes except for under high flows (0 to 10th percentile flows), where only 2 samples were collected. No consistent pattern in fecal coliform levels was observed across flow regimes. The highest violation rate (47%) was under wet conditions (from 10th to 40th percentile flows), but the next highest violation rate (30%) was under low flows (90th to 100th percentile flows).
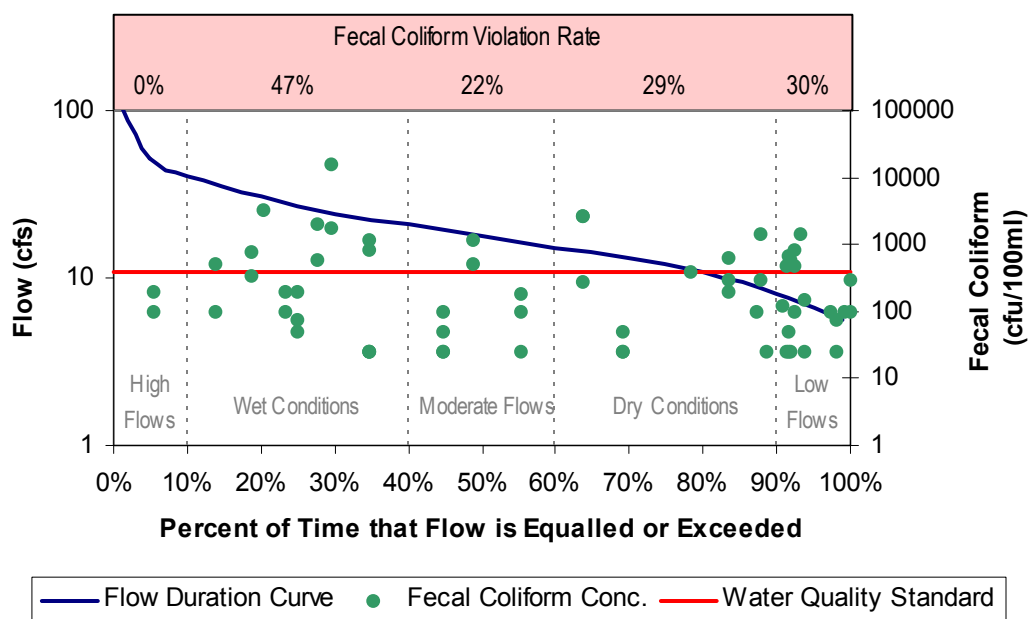
Figure 3-14. Fecal Coliform Concentrations and Violation Rates in Spout Run Under Various Flow Regimes.

3.8.4. Bacteria Source Tracking

Bacteria source tracking (BST) is an emerging analytical procedure to aid in identifying sources (i.e., human, pets, livestock, or wildlife) of fecal contamination in water bodies. BST helps to provided insight into the likely sources of fecal contamination, aids in distributing fecal loads from different sources during model calibration, and will improve the chances for success in implementing solutions. While there are several different analytical methodologies currently being used for BST (including DNA and RNA based methods), all studies conducted within the Spout Run watershed have used the Antibiotic Resistance Analysis (ARA) methodology. This approach is based on the premise that gut flora from different sources (i.e., human, pets, livestock, or wildlife) vary in their pattern of antibiotic resistance. Using this premise, colonies of fecal bacteria isolated from field collected water samples are exposed to a range of different antibiotics, and the patterns of resistance are recorded. These patterns are statistically compared to a known source library that contains the resistance patterns for fecal bacteria collected from a wide

variety of known sources. Based on comparison with the library, bacteria from the water sample are matched to the most likely source.

Several BST studies have been conducted in the Spout Run watershed. In 1997-1999, Hagedorn *et al.* (1999) conducted a BST study of Page Brook. In this study, fecal bacteria were enumerated and sources were estimated from samples collected at several locations along Page Brook. In 1997, fecal coliform levels in Page Brook were very high, averaging from 2347 to 42,400 cfu/100ml (Table 3-6). These high fecal coliform levels were determined to be predominantly from cows (78-86%), with small contributions from deer (5-6%) and geese (4-8%). In the second year of the study, agricultural best management practices (including livestock exclusion) were implemented along Page Brook above the monitoring stations. This resulted in a large reduction in monitored fecal coliform levels. Fecal coliform concentrations decreased by 60 to 96% in 1998. There was also a corresponding decrease in the percentage contribution from cows. Cows were still the largest contributor of fecal coliforms, but their contribution dropped by roughly half (from 78-86% to 37-44%). This study demonstrated that livestock are the primary contributors of fecal bacteria in the Page Brook watershed. It also demonstrated that agricultural best management practices are effective in reducing the contribution of fecal bacteria from livestock. As the contribution from livestock is controlled, fecal coliform concentrations decrease, and the contribution from wildlife becomes more relevant.

Table 3-6. Bacteria Source Tracking Results from Hagedorn *et al.*, 1999.

Year	Site	Fecal Coliform Conc. (cfu/100ml)	Average Source Contribution				
			Cow	Deer	Human	Geese	Unknown
1997	PB10	3103	81%	11%	0%	4%	4%
	PB12	42400	86%	6%	0%	5%	3%
	PB16	2347	78%	5%	0%	8%	9%
1998	PB10	347	38%	23%	0%	31%	8%
	PB12	1596	44%	19%	0%	30%	7%
	PB16	934	37%	28%	0%	24%	11%

In 1999-2000, a second BST study was conducted on the Spout Run watershed (Graves *et al.*, 2002). This study was aimed at investigating human sources of fecal bacteria to

Spout Run throughout the Millwood area. At this time individual homes in Millwood were served by on-site septic systems, and there was concern that with many older homes and a karst geology, septic waste may be entering Spout Run. In this study, the three major tributaries to Spout Run (Page Brook, Roseville Run, and Westbrook Run) were monitored as well as locations on Spout Run that represented Upper Millwood, Middle Millwood, Lower Millwood, and Below Millwood. Results were similar for the three tributaries (Table 3-7). Livestock sources dominated fecal coliform contributions at 59-65%. Wildlife contributions were slightly more than half of livestock contributions, and no human fecal coliform signal was observed. Through Millwood, human contributions were detected and represented 5-9% of the fecal coliform contribution. Contributions from livestock were slightly lower, and contributions from wildlife were slightly higher. Below Millwood, BST results were similar to the three tributaries, but with a lingering human signature.

Table 3-7. Bacteria Source Tracking Results from Graves *et al.*, 2002.

Stream	Frequency of Detection			Average Contribution		
	Human	Livestock	Wildlife	Human	Livestock	Wildlife
Page Brook	0%	100%	100%	0%	65%	33%
Roseville Run	0%	100%	100%	0%	62%	38%
Westbrook Run	0%	100%	100%	0%	59%	41%
Spout Run/Upper Millwood	89%	100%	100%	9%	52%	40%
Spout Run/Middle Millwood	40%	100%	100%	5%	54%	42%
Spout Run/Lower Millwood	40%	100%	100%	5%	47%	49%
Spout Run/Below Millwood	25%	100%	100%	2%	68%	31%

In 2007 and 2008, DEQ included Spout Run site 1BSPR000.40 in the state-wide BST monitoring program (Maptech, 2008). In this study, BST was performed on samples collected monthly over a 1-year period from July 2007 through June 2008. Table 3-8 shows the summarized results from this analysis. Livestock were the most frequently detected source and accounted for the highest percent contribution (44%). Human sources of fecal bacteria were higher than identified in previous studies, while wildlife

contributions were lower. Unlike the previous studies, this study included pets as a source category, and pets accounted for 18% of fecal bacteria isolates.

Table 3-8. Bacteria Source Tracking Results Collected by DEQ in 2007-2008.

Stream	Frequency of Detection				Average Contribution			
	Human	**Livestock**	**Wildlife**	**Pets**	**Human**	**Livestock**	**Wildlife**	**Pets**
Spout Run	67%	100%	75%	75%	21%	44%	17%	18%

It should be noted that BST results represent average contributions from a limited number of isolates collected from a limited number of discrete samples. Bacteria concentrations in flowing streams are highly variable, and the contribution of sources is likewise highly variable. For instance, in the BST samples collected by DEQ, livestock contributions ranged from 8% to 100% in individual samples. Human sources ranged from 0% to 50%, wildlife sources ranged from 0% to 58%, and pet sources ranged from 0% to 46% in individual samples. Due to this inherent variability, BST results are not used as the definitive predictor of bacteria sources. Rather, BST results were used alongside watershed and water quality modeling approaches and were considered during calibration of these models.

CHAPTER 4: STRESSOR IDENTIFICATION ANALYSIS

4.1. OVERVIEW

Benthic impairments are based on biological assessments of the benthic community. These biological assessments are effective at determining whether a water body is impaired or not, but they do not provide information on the stressor or source causing the impairment. To determine the cause of the impairment, a stressor identification analysis is conducted. VADEQ conducted this analysis according to EPA's Stressor Identification Guidance Document (USEPA, 2000). The first step in the stressor identification analysis is to list potential candidate stressors. VADEQ identified these from the listing information, monitoring data, scientific literature, and historic information. The next step is to analyze all of the available evidence to support or eliminate potential candidate stressors. VADEQ used physical, chemical, and biological data collected upstream and within the impaired reach to evaluate potential stressors. Based on the weight of evidence supporting each potential candidate, stressors were then separated into the following categories: non-stressor(s), possible stressor(s), and most probable stressor(s).

Once the most probable stressor(s) were identified, a causal analysis was conducted to directly link sources to the stressors and those stressors to the impairment. A conceptual model was developed to describe the causal pathways from source to stressor to impairment. The pathways in the conceptual model were then evaluated to determine if the existing data supported those mechanisms for producing the impairment.

4.2. BIOLOGICAL AND CHEMICAL DATA

VADEQ has three monitoring stations located within the Spout Run watershed. These stations are located on lower Spout Run, Page Brook Run, and Roseville Run. In addition, the Friends of the Shenandoah River (FOSR) also monitor three stations within the watershed (Figure 4-1). These stations monitor ambient water quality on Spout Run (FC02), Page Brook Run (FC09), and effluent quality from the Boyce STP (FC31).

George Mason University (GMU) has also conducted benthic monitoring within the Spout Run watershed at various locations. These stations have been monitored for various lengths of time and for various purposes. Table 4-1 shows the number of samples and the period of time over which individual stations were monitored. VADEQ's primary benthic and water quality monitoring station is near the mouth of Spout Run (1BSPR000.40) and is collocated with FOSR site FC02 and GMU site SR-621. This site contains the most robust monitoring data set and was the primary station used for the stressor identification analysis.

Table 4-1. Summary of Monitoring Stations in the Spout Run Watershed.

Station	Station Type	Benthic Sampling		Water Quality Sampling	
		Monitoring period	Samples Collected	Monitoring period	Samples Collected
1BSPR000.40	DEQ Benthic and Water Quality	1994-2007	8	1991-2007	89
1BPGE000.09	DEQ Water Quality			2001-2008	31
1BRSC001.42	DEQ Water Quality			1998-2008	21
FC02	FOSR Water Quality			1997-2008	200
FC09	FOSR Water Quality			1997-2008	183
FC31	FOSR Effluent Monitoring			1997-2008	203
PB-SH	GMU Benthic	1996-2001	8		
PB-Tree	GMU Benthic	1996-2001	6		
PB-OB	GMU Benthic	1996-2001	8		
PB-M	GMU Benthic	1996-2001	8		
PB-SU	GMU Benthic	1996-2001	7		
PB-SD	GMU Benthic	1996-2001	7		
PB-RR	GMU Benthic	1996-2001	7		
PB-617	GMU Benthic	1996-2001	7		
RR-M	GMU Benthic	1998-1999	4		
RR-SF	GMU Benthic	1998-1999	4		
WB-WF	GMU Benthic	1998-1999	4		
WB-SF	GMU Benthic	1998-1999	4		
SR-P	GMU Benthic	1999-2001	4		
SR-S	GMU Benthic	1999-2001	4		
SR-HC	GMU Benthic	1999-2001	4		
SR-621	GMU Benthic	1999-2001	4		
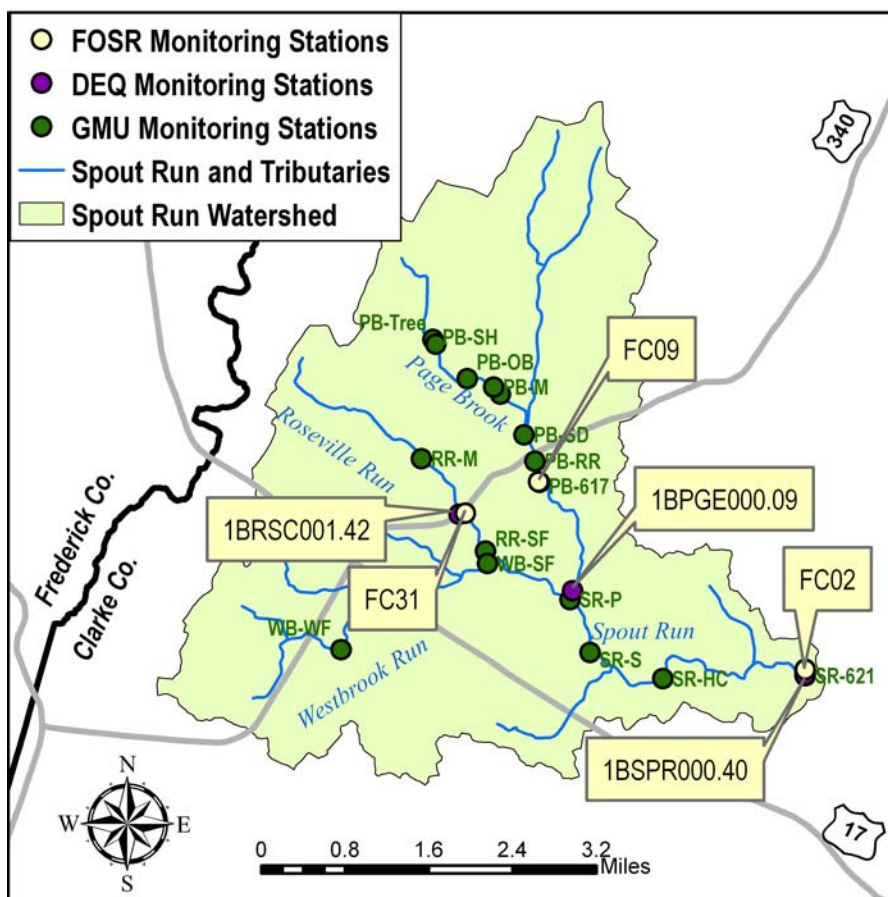
Figure 4-1. DEQ and Friends of the Shenandoah River Monitoring Stations in the Spout Run Watershed.

4.2.1. Benthic Assessments

From 1996 through 2001 George Mason University conducted benthic surveys in Page Brook, Roseville Run, Westbrook Run, and Spout Run (Jones and Hansen, 2002a; Jones *et al.*, 2002b; Jones *et al.*, 2002c). The average benthic condition index scores for the individual sites are shown in Table 4-2. Out of possible scores of 100, no site averaged greater than 60.7. All sites were classified as moderately or severely impaired.

Table 4-2. Benthic Scores in the Spout Run Watershed Measured by George Mason University.

Stream	Station	Average Benthic Score
Page Brook	PB-SH	23.5
	PB-Tree	28.6
	PB-OB	25.4
	PB-M	52.7
	PB-SU	21.3
	PB-SD	26.4
	PB-RR	40.8
	PB-617	55.0
Roseville Run	RR-M	17.9
	RR-SF	30.4
Westbrook Run	WB-WF	16.1
	WB-SF	57.2
Spout Run	SR-P	50.0
	SR-S	60.7
	SR-HC	50.0
	SR-621	57.1

VADEQ has also conducted benthic assessments near the mouth of Spout Run (station 1BSPR000.40) since 1994. The average Virginia Stream Condition Index (VSCI) score at this location is 41.21, well below the impaired threshold of 60. VSCI scores from 1994 through 2007 have ranged from 35 to 52 (Figure 4-2).
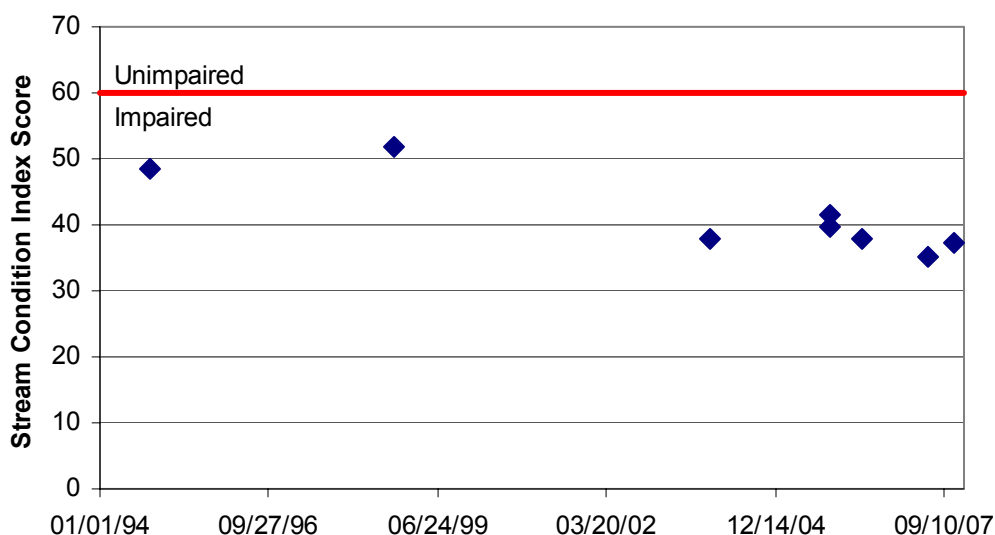
Figure 4-2. Benthic Assessment Scores for Spout Run.

To help investigate the cause of poor VSCI scores in Spout Run, taxa data and individual metrics from Spout Run were compared to relevant reference sites. Benthic references for Spout Run were identified by searching the VDEQ benthic assessment database for unimpaired streams of the same stream order and within the same ecoregion. A total of 8 second order streams within the Central Appalachian Ridge and Valley – Limestone/Dolomite Valley Ecoregion were identified as appropriate benthic references for Spout Run. These streams included Big Run, Beaver Creek, Pughs Run, and Passage Creek in the Shenandoah River drainage; Upper South Branch Potomac River in the Potomac River drainage; Falling Spring in the James River drainage; and Plum Creek and Toms Creek in the New River drainage.

When individual metrics from Spout Run are compared to reference sites, most all of the metrics are significantly lower in Spout Run (Figure 4-3). Only the % Chironomidae score in Spout Run is comparable to reference streams. Scores for richness; Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa; % Ephemeroptera; % Plecoptera and Trichoptera minus Hydropsychidae; % scrapers; % 2 dominant; and modified family biotic index (MFBI) in Spout Run were all well below respective scores in reference streams.

* Indicates statistically significant difference between Spout Run and reference
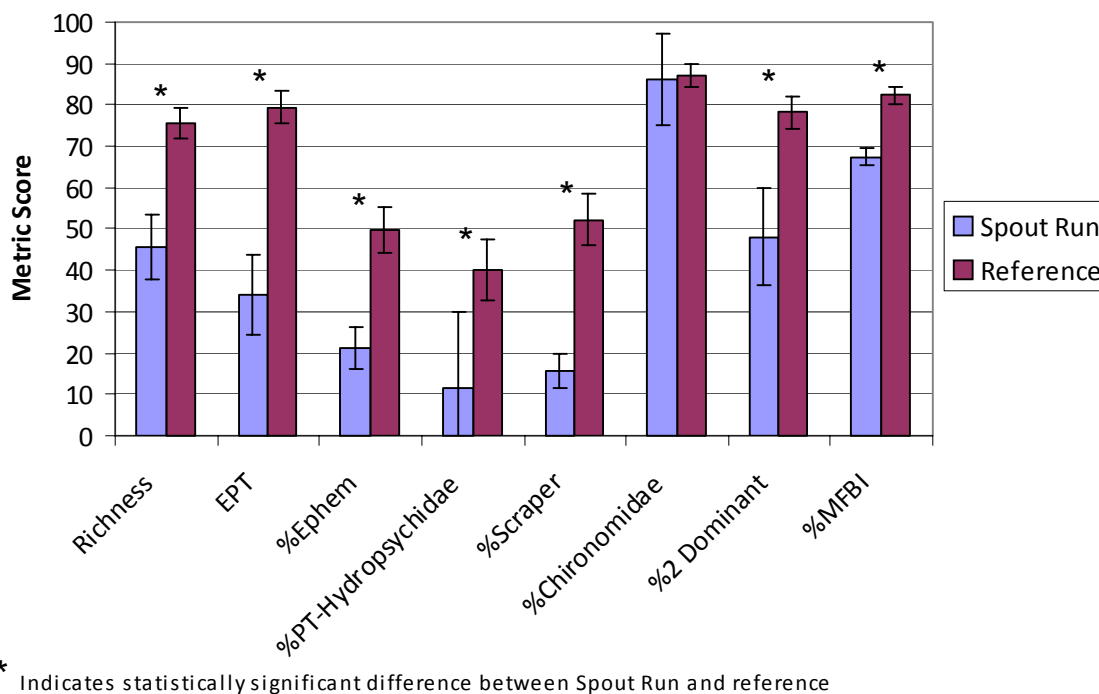
Figure 4-3. Virginia Stream Condition Metric Scores in Spout Run and Reference Watersheds.

Many of the low metric scores can be explained by a dominance of Hydropsychidae in Spout Run. Hydropsychidae is a family of net-spinning caddisflies, which spin nets of silk to trap particles as a food source. The Hydropsychidae are more pollution tolerant than most other Trichopteran families and can thrive in enriched and sediment laden environments. Figure 4-4 shows the predominance of Hydropsychidae in Spout Run compared to the more balanced community structure in reference streams. Hydropsychidae accounted for 47% of benthic macroinvertebrates in Spout Run and only 16% of macroinvertebrates in reference streams. This predominance of Hydropsychidae would directly lower % Ephemeroptera scores, % Plecoptera and Trichoptera minus Hydropsychidae scores, % scraper scores, % 2 dominant scores, and % MFBI scores.

Hydropsychidae are filter feeders that eat suspended material trapped on their nets. An increase in this family means an increase in the filter feeding niche. Figure 4-5 compares the functional feeding groups in Spout Run with those in reference streams. The niche

occupied by filter feeders in reference streams is only 24% of the community, while in Spout Run filter feeders comprise 52% of the community. To accommodate this increase in filter feeders, the collector, predator, and shredder niches in Spout Run decreased slightly (by <5%), and the scraper niche decreased sharply from 26% to 8%. This increase in the filter feeding niche in Spout Run indicates an over abundance of suspended matter that drives the community imbalance.
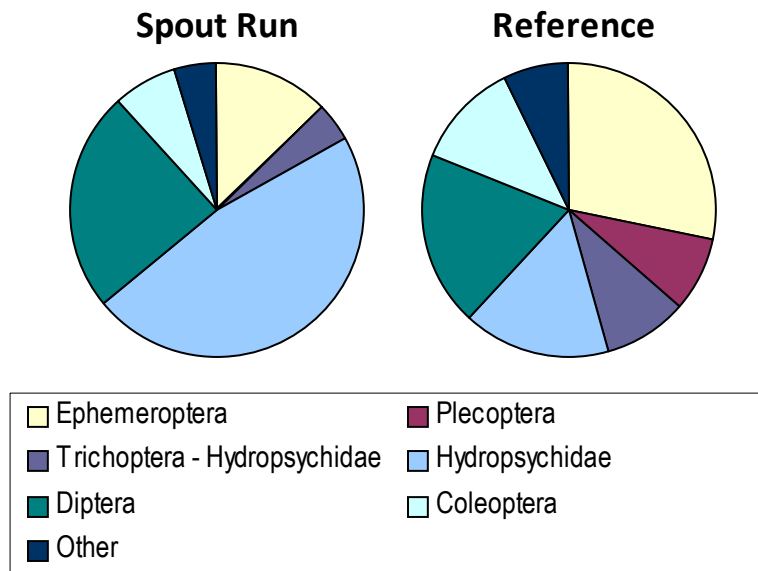
Figure 4-4. Taxonomic Community Structure in Spout Run and Reference Streams.
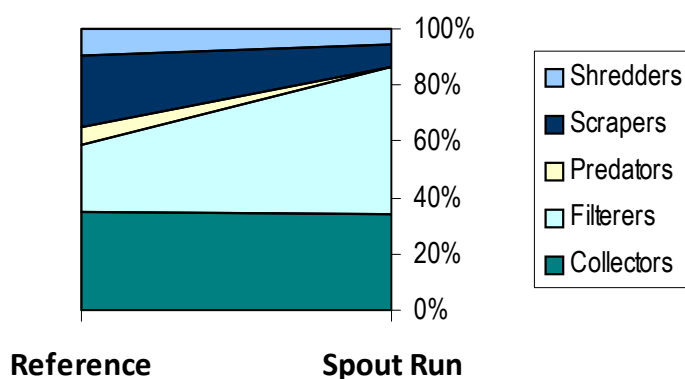
Figure 4-5. Function Feeding Group Structure in Spout Run and Reference Streams.

4.2.2. Habitat Assessments

As part of the Rapid Bioassessment Protocol, a visual habitat assessment is performed at the time of each sample collection. This assessment entails scoring each of a series of habitat components from 0 to 20. These habitat components include channel alteration, bank stability, bank vegetation, embeddedness, flow, riffles, riparian vegetation, sediment, substrate, and velocity. The individual scores for each of these measures are then added for a total habitat score. Figure 4-6 compares the total habitat scores in Spout Run with those from appropriate reference streams of the same stream order and within the same ecoregion. Total habitat scores averaged 132 in Spout Run and 159 in reference streams. Based on a statistical t-test assuming equal variances, the total habitat scores in Spout Run were significantly lower than in reference streams.

Individual habitat metrics are shown in Figure 4-7. Several habitat metrics (embeddedness, riffles, and sediment) were significantly lower (t-test with equal variances, alpha = 0.05) in Spout Run than in the reference streams. A significant reduction in these metrics indicates that habitat conditions related to sedimentation could be a potential stressor.
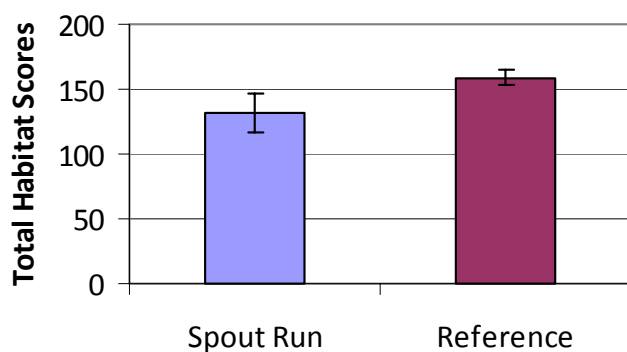
Figure 4-6. Total Habitat Scores for Spout Run and Reference Streams.
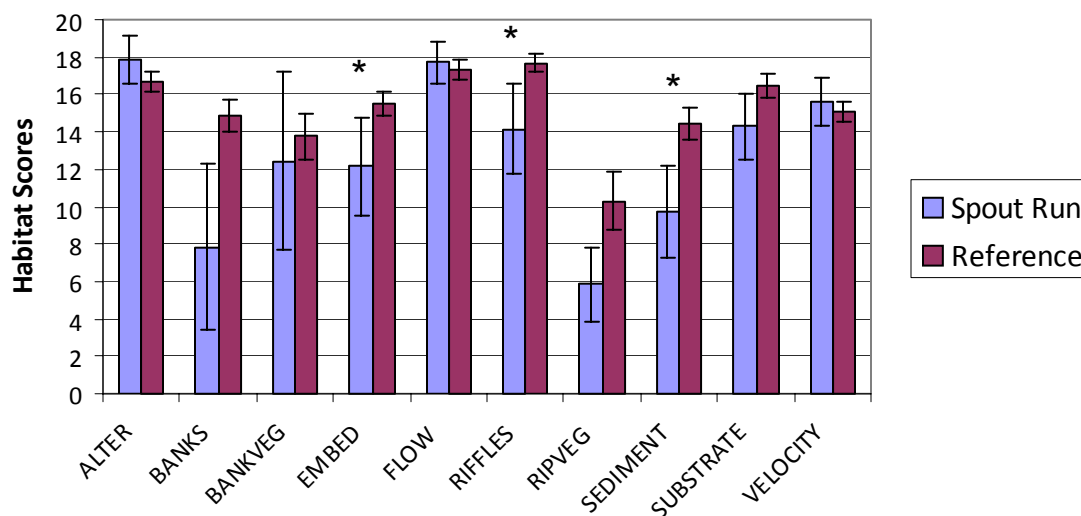
* Indicates statistically significant difference between Spout Run and reference

Figure 4-7. Individual Habitat Metric Scores for Spout Run and Reference Streams.

4.2.3. Water Quality Data

Since 1991, VADEQ has monitored a suite of water quality parameters at the primary Spout Run monitoring station (1BSRP000.40). The following water quality parameters were measured: temperature, pH, dissolved oxygen, conductivity, total suspended solids,

volatile solids, total dissolved solids, turbidity, ammonia, nitrite, nitrate, total Kjeldahl nitrogen, total nitrogen, total phosphorus, total organic carbon, biochemical oxygen demand, chemical oxygen demand, chloride, sulphate, sediment organics, sediment metals, and chlorophyll-A. At the same location, the FOSR have also measured a number of water quality parameters since 1997, including temperature, pH, dissolved oxygen, turbidity, nitrate, orthophosphate, and ammonia. Water quality information has also been collected by VADEQ and the FOSR at locations on Page Brook and Roseville Run, however, the stressor analysis will focus on data from Spout Run, since these data correlate spatially with the benthic impairment location.

4.2.3.1. Temperature

Temperatures measured in Spout Run by VADEQ and the FOSR are shown in Figure 4-8. Spout Run is designated as a stockable trout water and has a water quality standard of 21°C. Only 3 out of 129 measurements have exceeded that standard, and the maximum measured temperature was only 21.9°C. In addition to periodic temperature monitoring by VADEQ and the FOSR, temperature in Spout Run has been monitored continuously by the USGS since 2006. Figure 4-9 shows continuous temperature data. During the period of continuous monitoring, no measurements have exceeded the 21°C water quality standard.
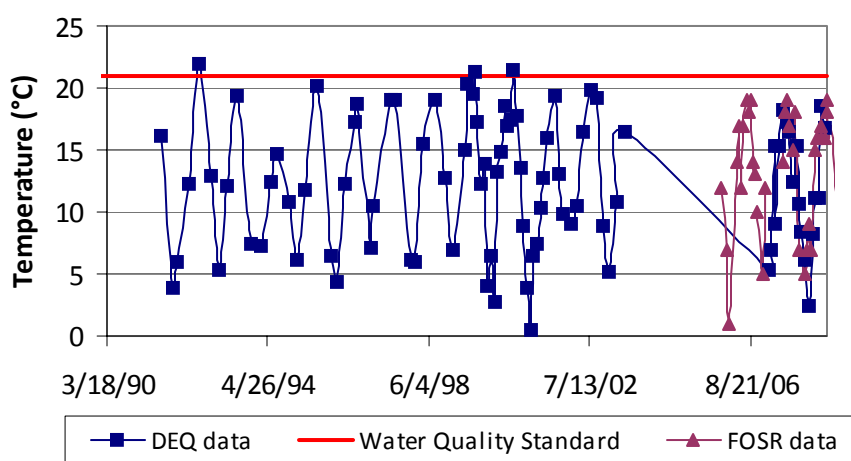
Figure 4-8. Temperature Measured in Spout Run by VADEQ and the FOSR.
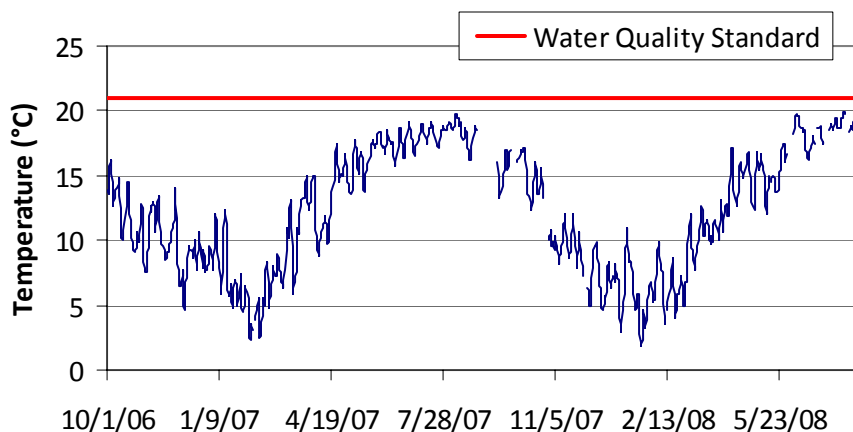
Figure 4-9. Continuous Temperature Monitoring Data for Spout Run.

4.2.3.2. pH

Measured pH values in Spout Run are shown in Figure 4-10. pH values measured by VADEQ averaged 7.99 and varied from 6.90 to 9.40. pH values measured by the FOSR ranged from 6.16 to 8.38 and averaged 7.87. Of the 278 pH values measured in Spout Run, only 1 exceeded the water quality standard range of 6.5 to 9.5 designated for Spout Run. This value was measured by the FOSR on 11/15/1997. It should be noted that VADEQ pH data are measured and recorded in the field, while FOSR pH results are measured in the laboratory following sample collection and transport. For this reason, pH data from the FOSR are not used by VADEQ for the purposes of determining impairments. These data, however, are used to supplement VADEQ data in a stressor analysis.
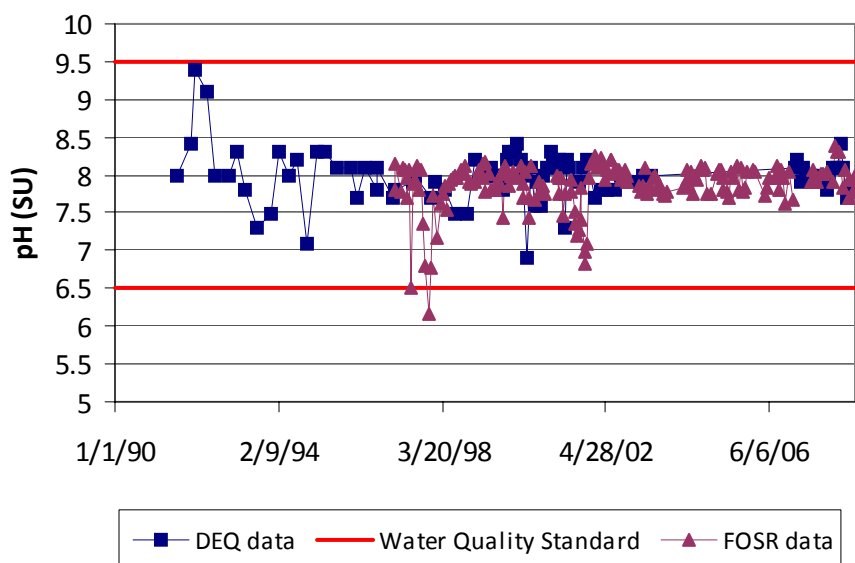
Figure 4-10. pH Measured in Spout Run by VADEQ and the FOSR.

4.2.3.3. Dissolved Oxygen

Measured dissolved oxygen values in Spout Run are shown in Figure 4-11. Dissolved oxygen values measured by VADEQ averaged 10.6 and varied from 7.1 to 15.4. Dissolved oxygen values measured by the FOSR ranged from 3.7 to 16.1 and averaged 9.4. Of the 268 dissolved oxygen values measured in Spout Run, only 2 exceeded the minimum water quality standard of 5.0 mg/L designated for Spout Run. These values were measured by the FOSR on 3/28/1998 and 3/27/1999. It should be noted that VADEQ dissolved oxygen data are measured and recorded in the field, while FOSR results are measured in the laboratory following sample collection and transport. For this reason, dissolved oxygen data from the FOSR are not used by VADEQ for the purposes of determining impairments. These data, however, are used to supplement VADEQ data in a stressor analysis.

In addition to periodic dissolved oxygen measurements, VADEQ conducted continuous monitoring of diurnal dissolved oxygen patterns in Spout Run. During a 4-day period in August 2007, VADEQ measured dissolved oxygen at 10-minute intervals. Diurnal monitoring of dissolved oxygen is important, because critical dissolved oxygen levels are

typically encountered just before sunrise. This is due to the combination of oxygen consumption from respiration and the absence of oxygen production from photosynthesis during the night. Diurnal monitoring was conducted in August, because critical dissolved oxygen levels are also more common during the hot and dry late summer months. During diurnal dissolved oxygen monitoring in Spout Run, dissolved oxygen levels were well above the water quality standard of 5 mg/L (Figure 4-12). Nighttime minimum dissolved oxygen levels fell no lower than 7.96 mg/L.
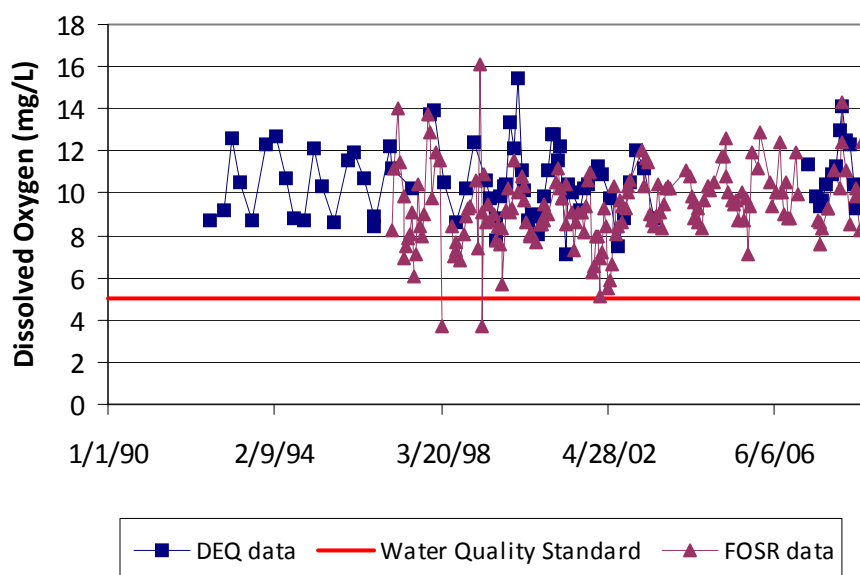
Figure 4-11. Dissolved Oxygen Measured in Spout Run by VADEQ and the FOSR.
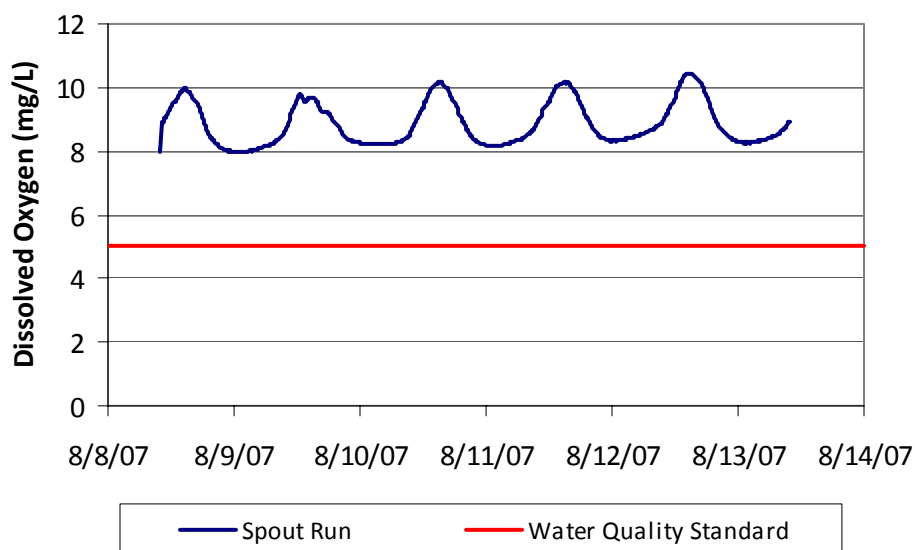
Figure 4-12. Diurnal Dissolved Oxygen Pattern in Spout Run in August 2007.

4.2.3.4. Conductivity and Dissolved Solids

Conductivity is a measure of the electrical potential of water based on the ionic charges of dissolved compounds. For this reason, the conductivity of water is closely related to the total dissolved solids present. Conductivity has been periodically measured in Spout Run by VADEQ since before 1990, and the USGS has continuously measured conductivity at the gaging station since 2006. Conductivity levels measured by VADEQ at station 1BSPR000.40 have ranged from 440 to 627 and averaged 543 umohs/cm (Figure 4-13).   Continuously monitored conductivity values measured by USGS have ranged even higher (up to 857 umohs/cm) and have averaged 569 umohs/cm (Figure 4-14).   Conductivity results from Spout Run are consistently higher than the 90th percentile of statewide probabilistic data (313 umhos/cm), but this is consistent with the strong spring influence on Spout Run.

Spout Run was also much higher in conductivity than the eight benthic reference sites, but not all of these locations are predominantly spring fed. The eight benthic reference sites averaged only 226 umhos/cm in conductivity, compared to 543 umhos/cm in Spout

Run. When a subset of reference streams with strong spring influence was considered, however, conductivity results were more comparable between Spout Run and the selected references (Pugh's Run and Plum Creek). Figure 4-15 shows the conductivity and total dissolved solids in Spout Run compared to the selected spring-dominated references. Conductivity in Spout Run was still statistically higher than in the selected reference streams, but total dissolved solids were not significantly different.
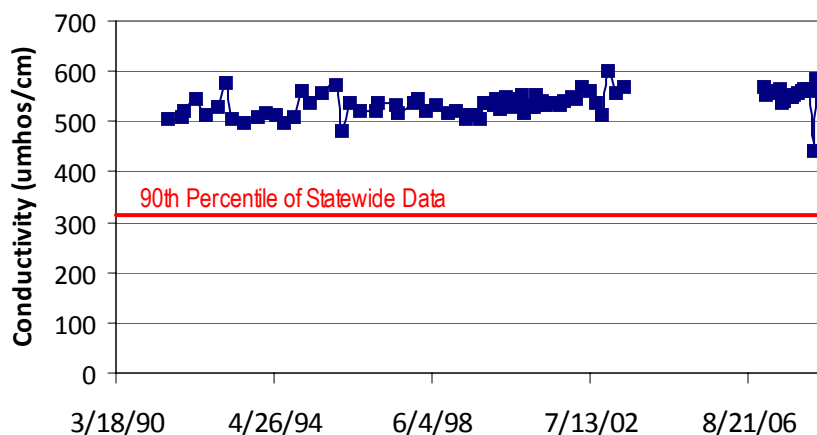
Figure 4-13. Periodic Conductivity Measurements in Spout Run.
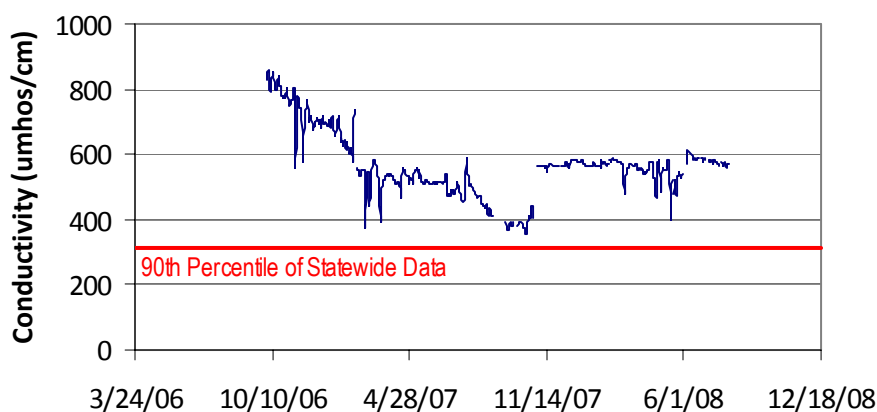
Figure 4-14. Continuous Conductivity Measurements in Spout Run.
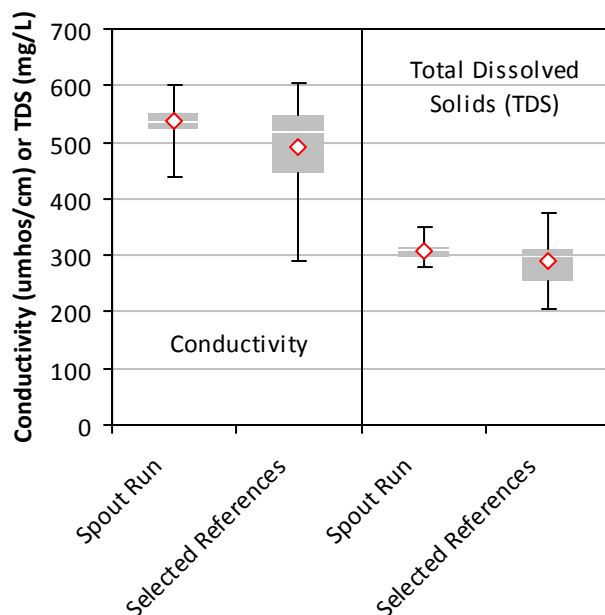
Figure 4-15. Conductivity and Total Dissolved Solids in Spout Run and Selected Reference Streams.

4.2.3.5. Solids

Total suspended solids (TSS) were measured in Spout Run, Page Brook, and Roseville Run. Concentrations ranged from the detection limit of 3 mg/L to 115 mg/L, with an average of 8.4 mg/L (Figure 4-16). Figure 4-17 compares the cumulative distribution function of TSS in Spout Run with the eight benthic reference streams. This analysis revealed that TSS values from the 30th to 90th percentile were higher in Spout Run than in reference streams. Spout Run TSS values were up to 133% higher than reference TSS values of the same frequency. This indicates that Spout Run exhibits elevated sediment levels more frequently than reference streams of similar size and ecoregion.

Sediment load duration curves were developed to compare sediment loads in Spout Run under varying flow regimes with regional references. Of the eight regional reference streams selected for comparison with Spout Run, flow data were only available for one reference (Passage Creek). Flow and TSS concentrations from Passage Creek and Spout Run were used to develop sediment rating curves that relate the load of sediment in each

stream as a function of flow (Figure 4-18). The sediment rating curves show that at equivalent flows, Spout Run carries more sediment than Passage Creek. The regression equation from these sediment rating curves were used to produce sediment load duration curves for each stream based on the flow frequency of Spout Run (Figure 4-19). This figure shows that at all flow frequencies, Spout Run carries a higher load of sediment than a comparable reference. At an average annual flow of 23 cfs, Spout Run carries approximately 0.46 T/d of sediment compared to only 0.21 T/d at equivalent flow in the reference. This represents 2.2 times the reference sediment load.
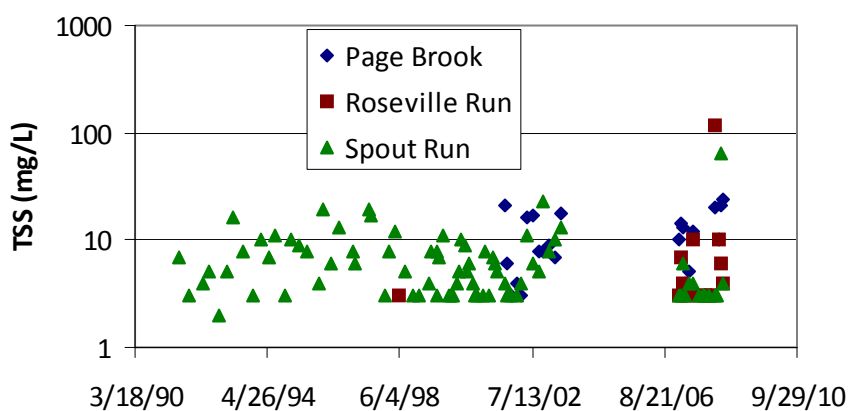
Figure 4-16. Total Suspended Solids in Spout Run.
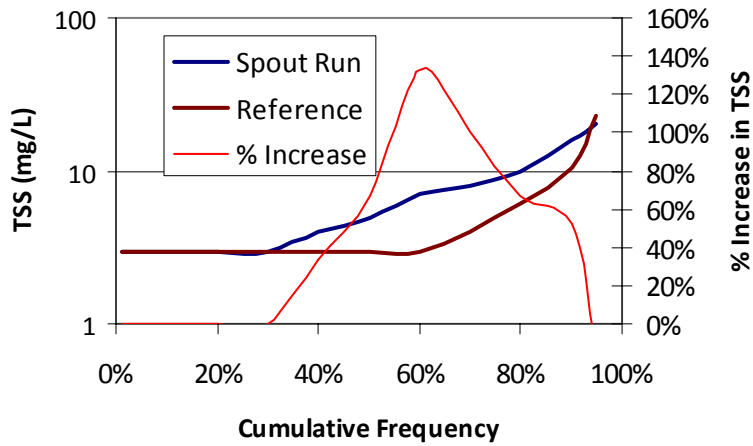
Figure 4-17. Cumulative Distribution Function of Total Suspended Solids in Spout Run and Regional Reference Streams.
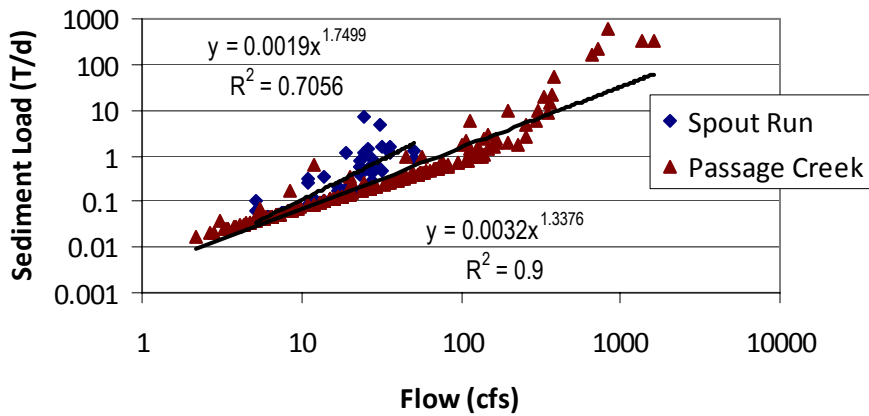
Figure 4-18. Sediment Rating Curves for Spout Run and a Regional Reference (Passage Creek).
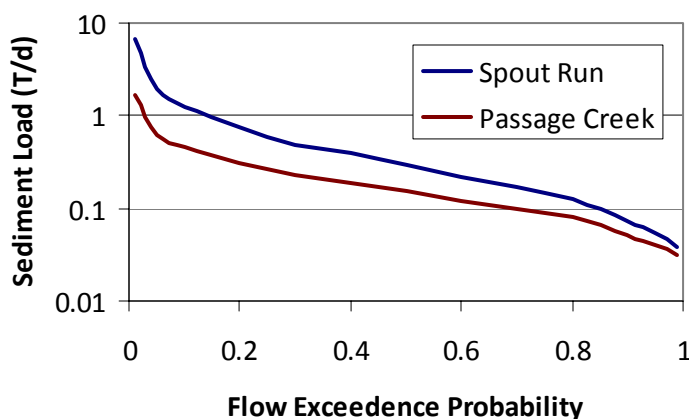
Figure 4-19. Sediment Load Duration Curves for Spout Run and a Regional Reference (Passage Creek).

4.2.3.6. Organic Matter

VADEQ measured various indicators of organic matter including: total volatile solids (VS), total organic carbon (TOC), dissolved organic carbon (DOC), biological oxygen demand (BOD), and chemical oxygen demand (COD). A comparison of these measurements in Spout Run and regional references is presented in Figure 4-20 and Figure 4-21. BOD levels in Spout Run were very low (averaging 1.62 mg/L) and were not statistically different from BOD levels in reference streams (using a t-test with alpha = 0.05). COD levels in Spout Run averaged 7.13 mg/L and were also not statistically different from COD levels in reference streams. TOC levels in Spout Run, averaging 1.92 mg/L, were significantly lower than TOC levels in reference streams, which averaged 2.85 mg/L.

Total volatile solids in Spout Run were significantly higher than in reference streams (using a t-test with alpha = 0.05). VS levels in Spout Run averaged 54.7 mg/L, compared to 36.1 mg/L in reference streams. While this could indicate organic matter enrichment, it is more likely that the higher VS levels in Spout Run are simply reflective of higher suspended solids loads. Total solids in Spout Run averaged 329.6 mg/L compared to only 140.2 mg/L in reference streams. When the percent volatile solids are calculated, Spout Run contains a lower percentage of volatile solids (17%) than the reference

streams (26%). This means that Spout Run is enriched with solids, but these solids contain less organic matter than typical solids in reference streams.
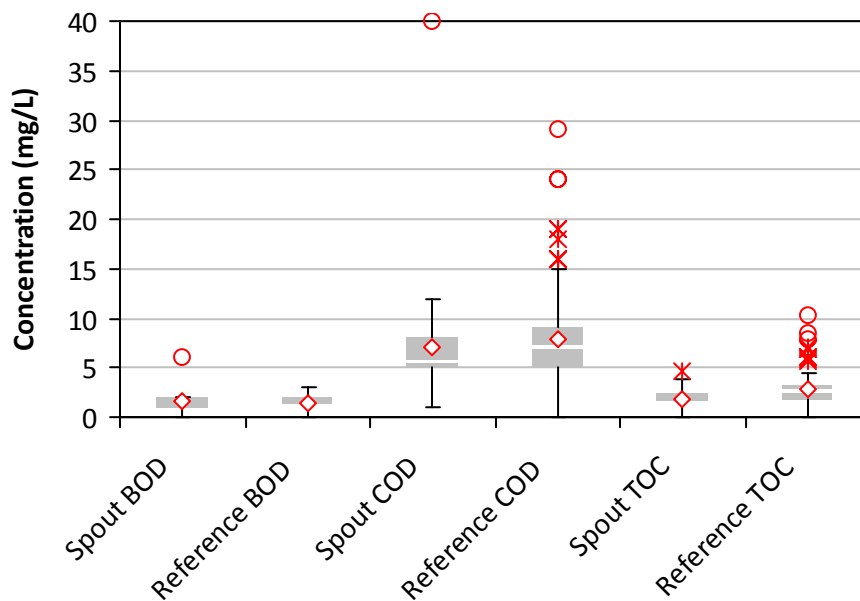
Figure 4-20. Various Measurements of Organic Solids in Spout Run and Regional Reference Streams.
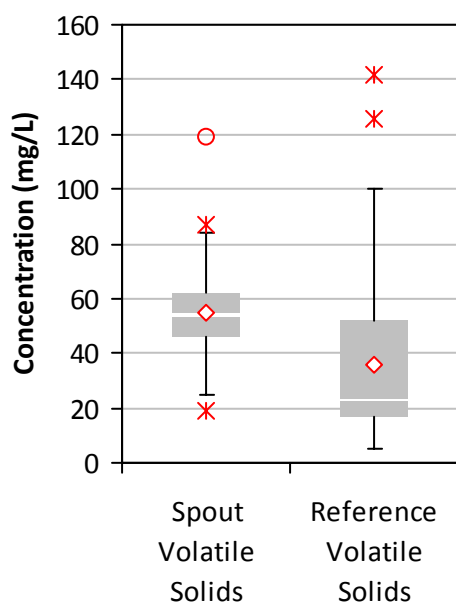
Figure 4-21. Total Volatile Solids in Spout Run and Regional Reference Streams.

4.2.3.7. Nutrients

VADEQ measured the following nutrient components in Spout Run: ammonia, nitrite, nitrate, total nitrogen, total Kjeldahl nitrogen (TKN), and total phosphorus. In addition, the FOSR measured nitrate, ammonia, and orthophosphate. Ammonia is a reduced form of nitrogen that can be toxic at certain temperatures and pHs. Figure 4-22 shows the ammonia levels measured in Spout Run along with corresponding water quality standards that are pH and temperature dependent. No VADEQ-collected results exceeded water quality standards for ammonia, and only one FOSR-collected result exceeded the standard. This particular result, along with the rest of FOSR ammonia results collected prior to 2001 is suspect. FOSR ammonia results collected prior to 2001 were consistently higher than VADEQ-collected results during the same time period and were consistently higher than FOSR-collected results after 2001. It is possible that the method of ammonia analysis conducted by FOSR changed in 2001.

Figure 4-23 compares the levels of different nitrogen forms in Spout Run with reference streams. The vast majority of nitrogen in Spout Run is in the form of nitrate, with total nitrogen concentrations averaging 2.38 mg/L and nitrate concentrations averaging 2.36 mg/L. Both total nitrogen and nitrate levels in Spout Run were significantly higher than levels in regional reference streams (using a t-test with alpha = 0.05). Other forms of nitrogen (nitrite and TKN) were low and were not significantly higher in Spout Run than in reference streams.

While nitrogen in Spout Run exceeded regional reference streams, the impact of elevated nitrogen levels must be viewed in the light of limiting nutrients. The typical ratio of nitrogen to phosphorus in algae is 7.5:1, so ratios above 7.5 indicate that phosphorus is the limiting nutrient and ratios below 7.5 indicate that nitrogen is the limiting nutrient. In Spout Run, the nitrogen to phosphorus ratio is 42.7, so phosphorus is by far the limiting nutrient controlling algal growth. This means that the levels of phosphorus in Spout Run are much more important than nitrogen levels, and nitrogen alone cannot produce conditions of eutrification. Figure 4-24 compares the levels of total phosphorus in Spout Run with regional reference streams. Phosphorus levels in Spout Run were relatively low and not significantly different from regional reference streams.
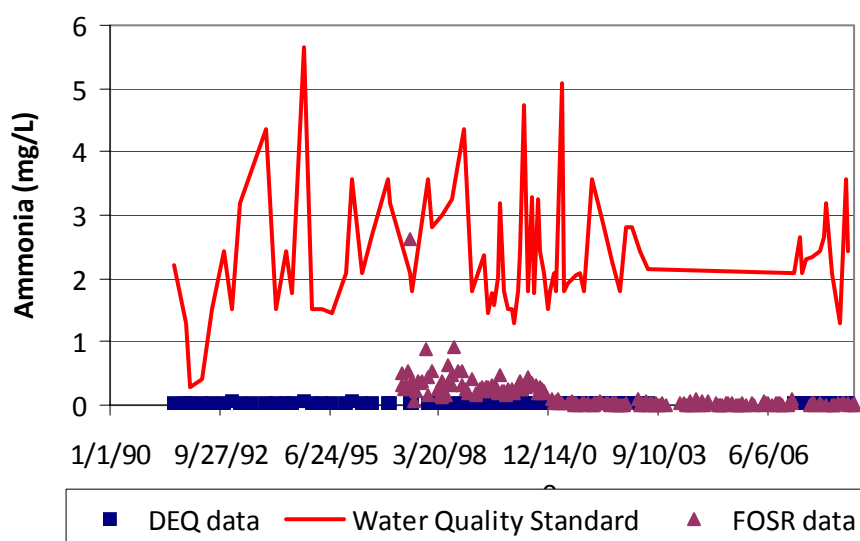
Figure 4-22. Ammonia in Spout Run.
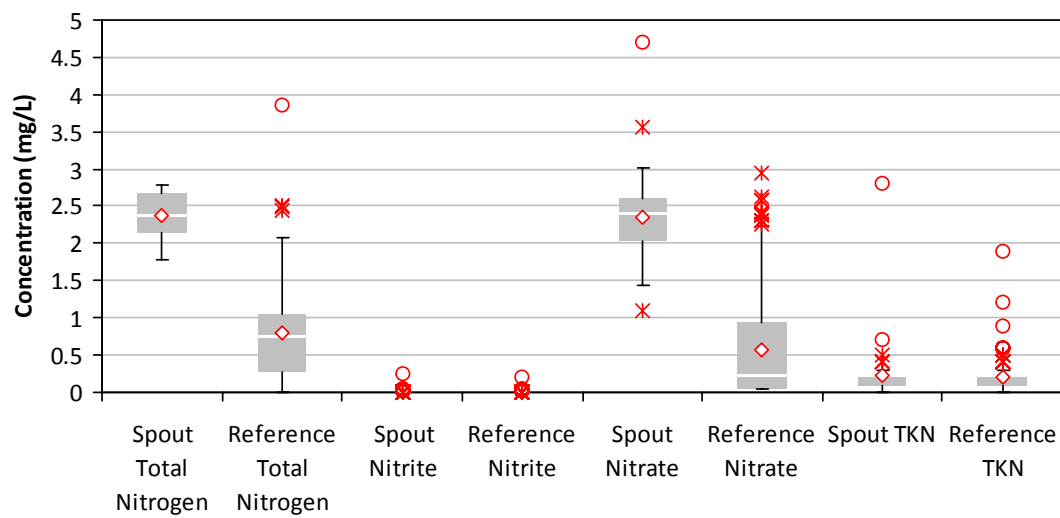
Figure 4-23. Nitrogen Forms in Spout Run and Regional Reference Streams.
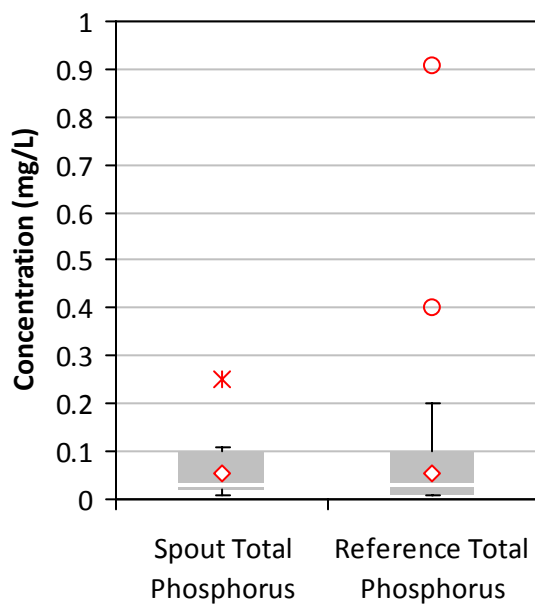
Figure 4-24. Total Phosphorus in Spout Run and Regional Reference Streams.

4.2.3.8. Toxics

VADEQ monitored the levels of toxic organics and metals in sediments from Spout Run. Table 4-3 shows the measured levels of toxic organics in Spout Run compared to probable effect concentrations (PECs) that would be likely to cause benthic impairment. No toxic organics were measured above detection limits or PEC values. Table 4-4 shows the measured levels of toxic metals in Spout Run sediments.   None of these metals exceeded PECs, indicating that toxicity due to sediment metals or organics is not likely.

Table 4-3. Levels of Toxic Organic Compounds in Spout Run Sediments.

Organic Compound	# Samples	Maximum Measured Conc. (ppm)	Probable Effect Conc. (ppm)	PEC Exceeded?
Pentachlorophenol	2	<90		N
Aldrin	2	<100		N
Chlordane	2	<500	17.6	N
DDD	2	<100	28	N
DDE	2	<100	31.3	N
DDT	2	<100	62.9	N
Dieldrin	2	<100		N
Endrin	2	<100		N
Toxaphene	2	<190		N
Heptachlor	2	<20	16	N
Total PCBs	2	<500	676	N
Heptachlor epoxide	2	<100		N
Dicofol	2	<100		N

Table 4-4. Levels of Toxic Metals in Spout Run Sediments.

Metal	# Samples	Maximum Measured Conc. (ppm)	Probable Effect Conc. (ppm)	PEC Exceeded?
Arsenic	2	<5	33	N
Beryllium	2	<5		N
Cadmium	2	<5	4.98	N
Chromium	2	12	111	N
Copper	2	68	149	N
Lead	2	13	128	N
Manganese	1	233		N
Nickel	2	<5	48.6	N
Silver	2	<5		N
Zinc	2	102	459	N
Antimony	1	9		N
Aluminum	1	5640		N
Selenium	2	<1		N

Iron	1	9510		N
Thallium	1	<5		N
Mercury	2	<0.3	1.06	N

4.3. NON-STRESSORS

4.3.1. Temperature

Temperatures in Spout Run are very cool due to the spring influences. No violations of the temperature standard have occurred, and temperature is not believed to be a stressor on the benthic community that is responsible for the impairment.

4.3.2. pH

All VADEQ-measured pH values were within the water quality standard range and within the tolerance ranges for benthic macroinvertebrates. pH is not believed to be a stressor on the benthic community that is responsible for the impairment.

4.3.3. Dissolved Oxygen

All VADEQ-measured dissolved oxygen values, including diurnal patterns under critical conditions, were above the minimum water quality standard and within the tolerance ranges for benthic macroinvertebrates. Dissolved oxygen is not believed to be a stressor on the benthic community that is responsible for the impairment.

4.3.4. Organic Matter

Relevant measures of organic matter in Spout Run, such as BOD, COD, and TOC, were comparable to levels in unimpaired regional reference streams. Only total volatile solids were significantly greater in Spout Run than reference streams, however, this is explained by greater overall loads of suspended solids in Spout Run. For these reasons, organic matter is not considered to be a stressor on the benthic community that is responsible for the impairment.

4.3.5. Toxics

Ammonia levels in Spout Run were well below water quality standards. Other measured toxics in Spout Run sediments were all either below detection or below levels expected to cause toxicity to benthic macroinvertebrates. In addition, some sensitive taxa were present, indicating that toxicity was not the cause of the benthic impairment. For these reasons, toxics are not considered to be a stressor on the benthic community that is responsible for the impairment.

4.4. POSSIBLE STRESSORS

4.4.1. Conductivity and Dissolved Solids

Due to the heavy influence of limestone springs in the watershed, Spout Run contains moderately high levels of conductivity and dissolved solids. Conductivity in Spout Run averages 543 umhos/cm, and Pond (2004) showed that on surface mined lands *Ephemeroptera* taxa decreased significantly at conductivity levels much above 500 umhos/cm. On surface mined lands, however, the dissolved constituents would be expected to be much different than the calcium carbonate dominated Spout Run. When compared to other reference spring creeks with unimpaired benthic communities, Spout Run was not statistically different in dissolved solids, but was still statistically higher in conductivity. It is possible that the high conductivity and high dissolved solids water chemistry in Spout Run could alter the benthic macroinvertebrate assemblage, but other spring creeks are similar and have unimpaired benthic conditions. For these reasons, total dissolved solids in Spout Run were considered a possible stressor.

4.4.2. Nutrients

Levels of total nitrogen and nitrate in Spout Run are significantly higher than in unimpaired regional reference streams. The nitrogen to phosphorus ratio in Spout Run, however, indicates that algal growth is limited by phosphorus and not nitrogen. Total phosphorus levels in Spout Run are not significantly different from unimpaired references, so eutrification from nutrient enrichment is not expected to significantly impact benthic health. For these reasons, nutrients were considered a possible stressor.

4.5. MOST PROBABLE STRESSOR

4.5.1. Sediment

Multiple lines of evidence suggest that sediment is the most probable stressor of the benthic community in Spout Run. The first line of evidence is the biological taxa data from Spout Run. Most of the poor benthic scores in Spout Run are explained by an abundance of Hydropsychidae that have crowded out other taxa and other feeding niches. The Hydropsychidae are net-spinning caddisflies that feed on suspended particles trapped on their nets. The predominance of Hydropsychidae means an over abundance of suspended material in the water that allows the filter feeding niche to expand and crowd out other feeding guilds. This phenomenon can be seen when the community structure and feeding groups in Spout Run are compared to unimpaired regional references (Section 4.2.1).

The second line of evidence supporting sediment as the most probable stressor is information from habitat assessments. Habitat scores for embeddedness and sediment were significantly reduced in Spout Run compared to unimpaired regional references. These assessments indicate that suspended sediment is being deposited and accumulating in Spout Run such that bottom substrate is being covered and available benthic habitat is being reduced. Figure 4-25 - Figure 4-27 show visual evidence of degraded habitat conditions in Spout Run that indicate a sediment stressor. Near the benthic monitoring station at 1BSPR000.40, the banks of Spout Run are badly incised and actively eroding (Figure 4-25). At that location, deposited sediments in slower moving pools were several feet thick. In faster flowing areas, the bottom substrate remained largely embedded (Figure 4-26). Visual evidence on 6/13/08 also showed turbid conditions in Page Brook even though stream flows were low and there had been no antecedent precipitation.

The third line of evidence supporting sediment as the most probable stressor includes TSS measurements and sediment load calculations. When the cumulative distribution function of TSS measurements in Spout Run and reference watersheds were compared, Spout Run contained a higher frequency of elevated TSS concentrations. Using flow

measurements to translate TSS concentrations into sediment loads also revealed that Spout Run carries significantly more sediment than an unimpaired reference stream.

The final line of evidence supporting sediment as the most probable stressor involves an analysis of relative bed stability conducted on Spout Run. In August 2008, VADEQ conducted a detailed physical habitat assessment of Spout Run according to EPA methods for *Quantifying Physical Habitat in Wadeable Streams* (Kaufmann *et al*., 1999). This analysis involved the measurement of channel dimensions and substrate composition at numerous transects within a 400 m stream reach surrounding the benthic monitoring station. From this analysis, the reach was determined to be comprised of 71.4% fines, exhibit 79.8% embeddedness, and score a log relative bed stability index (LRBS) of -1.18. LRBS scores of <1.0 are considered to represent systems that are unstable and accumulating in sediment. This is confirmed by high percent embeddedness and percent fines scores, which also indicate a higher than typical sediment load.

Figure 4-25. Visual Evidence of Bank Erosion in Spout Run (picture taken 6/13/08 by R. Brent)

Figure 4-26. Visual Evidence of Embedded Substrate in Spout Run (picture taken 6/13/08 by R. Brent)

Figure 4-27. Visual Evidence of Turbid Water Quality in Page Brook (picture taken 6/13/08 by R. Brent).

4.6. CONCEPTUAL MODEL AND CAUSAL ANALYSIS

Based on the observed data and analysis of potential stressors, a conceptual model was developed to describe the causal relationships between the source of the impairment, the most probable stressors, and the observed loss of benthic macroinvertebrates. Figure 4-28 shows the conceptual model for benthic impairment in Spout Run. In this conceptual model, an increased particulate load (i.e., suspended sediment) is identified as the stressor. The conceptual model shows several different pathways linking this stressor to sources of sediment. These pathways include watershed soils that are eroded or washed off of the land surface during storm events, deposited instream sediments that are resuspended during higher flows, and stream bank sediments that are eroded. Multiple lines of evidence support these pathways including visual evidence, suspended sediment monitoring, habitat evaluations, relative bed stability measurements, and sediment loading calculations.

The consistently increased particulate load in Spout Run then acts to biologically impair the stream through two pathways: a change in feeding niches to favor filter feeders, and the filling of interstitial spaces that reduces available habitat. Benthic taxa data provide evidence of these pathways with an observed increase in filter feeders and a decrease in taxa richness. Habitat assessments and relative bed stability analysis also provide evidence of interstitial filling. The combined weight of evidence described above (Section 4.5.1) supports the conceptual model of sediment as a stressor in Spout Run. Significant evidence links the sources, stressor, and biological impairment as described in the conceptual model (Figure 4-28).
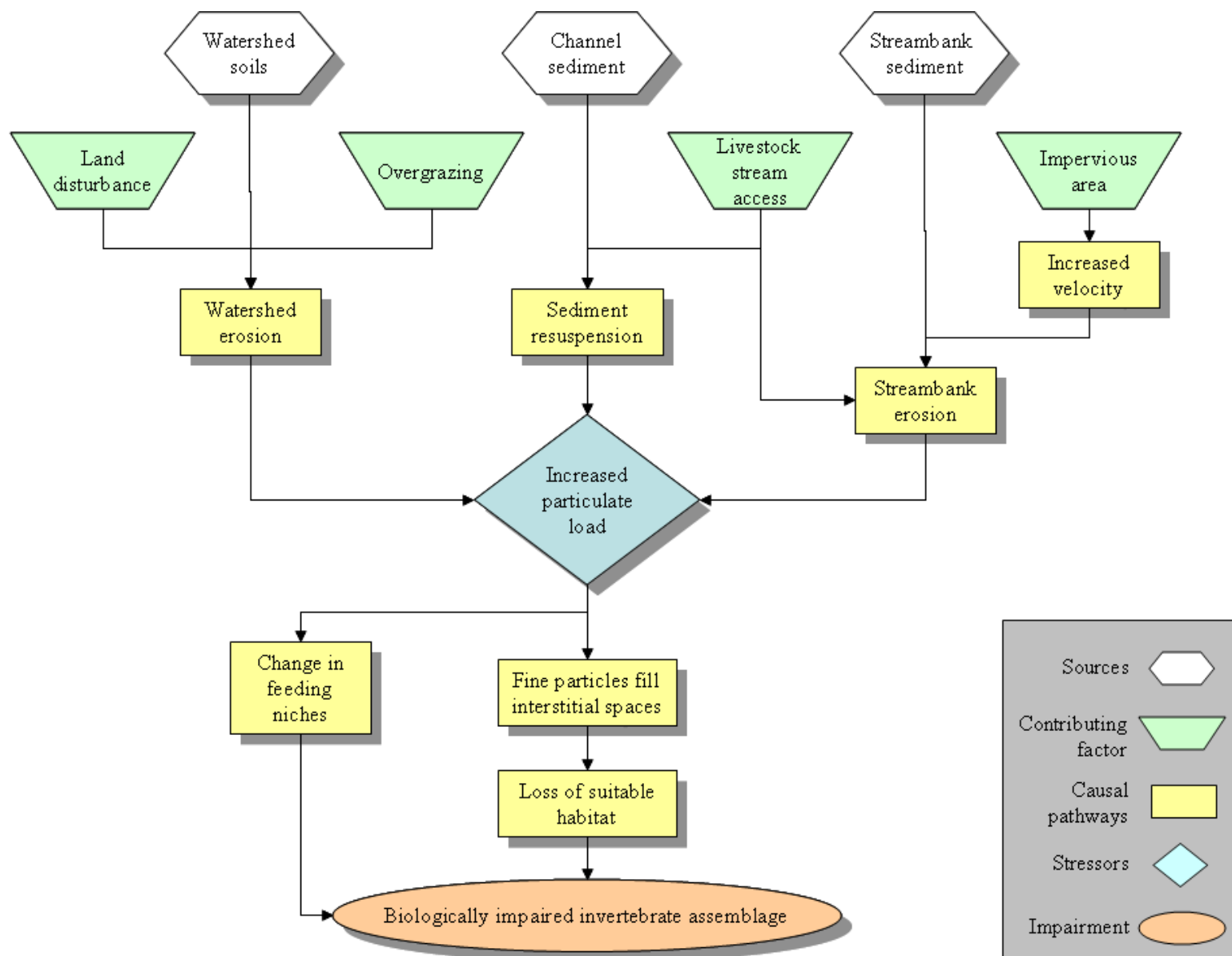
Figure 4-28. Conceptual Model for the Cause of Benthic Impairment in Spout Run.

CHAPTER 5: SOURCE ASSESSMENT OF FECAL COLIFORM

Fecal coliform sources in the Spout Run watershed were assessed using information from the following sources: VADEQ, Virginia Department of Conservation and Recreation (VADCR), Clarke County, U.S. Census Bureau, Virginia Department of Agriculture and Consumer Services (VDACS), Virginia Department of Game and Inland Fisheries (VADGIF), Lord Fairfax Soil and Water Conservation District, public participation, watershed reconnaissance and monitoring, published information, and professional judgment. Fecal coliform sources in the watershed include humans, pets, livestock, and wildlife. Point and nonpoint human sources are present. This section describes and quantifies the fecal coliform loads from each source within the watershed.

5.1. PERMITTED POINT SOURCES

Within the Spout Run watershed, there are two dischargers that hold individual Virginia Pollutant Discharge Elimination System (VPDES) permits. These include the Boyce Sewage Treatment Plant (STP) (VA0085171) and the Prospect Hill Springs Water Treatment Plant (WTP) (VA0090883). Figure 5-1 shows the location of these point sources, and Table 5-1 shows the allocated bacteria load for these facilities. The Boyce STP is permitted to discharge up to 0.05 million gallons per day (MGD) of treated sewage with an *E. coil* concentration less than 126 cfu/100ml. Typical flows from this facility are considerably less than the permitted flow and have averaged 0.027 MGD since 2001. The Prospect Hill Springs WTP filters spring water as a drinking water source and discharges filter backwash water. This facility does not contribute fecal coliform to Spout Run, but does contribute solids. No other point sources discharge within the watershed.

Table 5-1. Permitted Bacteria Point Sources in the Spout Run Watershed.

Facility	Permit #	Permitted Flow (MGD)	Permitted Fecal Conc. (cfu/100ml)	Permitted E. coli Conc. (cfu/100ml)	Permitted Fecal WLA (cfu/yr)	Permitted E. coli WLA (cfu/yr)
Boyce STP	VA0085171	0.05	200	126	1.38E+11	8.70E+10
Prospect Hill Springs WTP	VA0090883	0.0181	NA	NA	0	0
Total					1.38E+11	8.70E+10
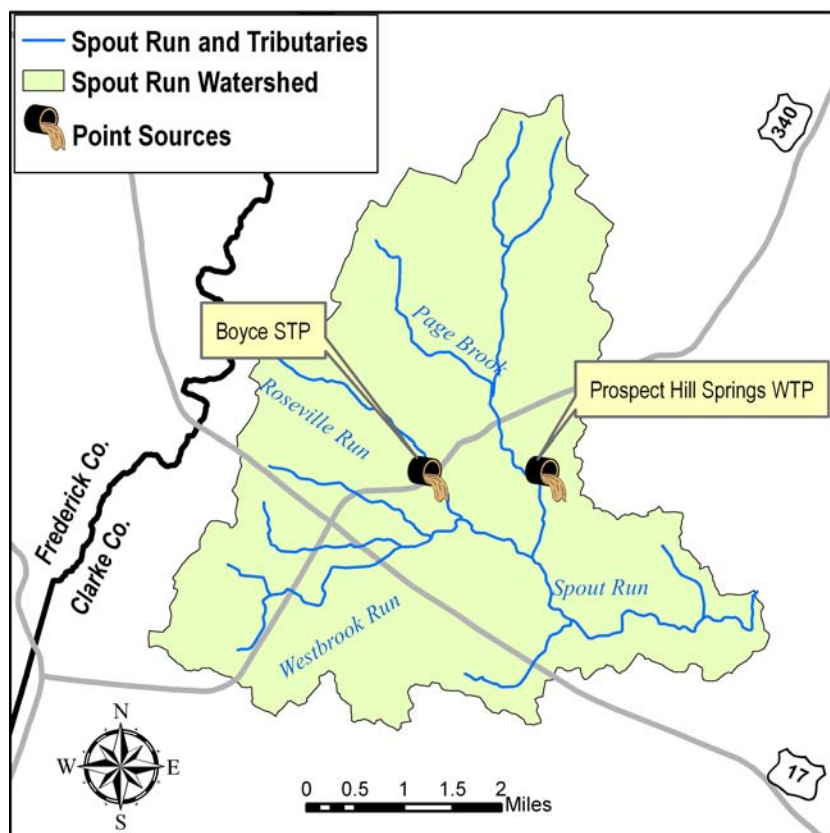
Figure 5-1. Point Source Dischargers in the Spout Run Watershed.

5.2. HUMANS

The human population in the Spout Run watershed was calculated from a combination of Clarke County structures data and census block level data obtained in the 2000 U.S. census (Census Bureau, 2000). The Clarke County structures database is more up-to-date than 2000 census data, so it was used to identify homes within the Spout Run watershed (Figure 5-2). Census block data were then used to estimate the number of people within each home. Each home was assigned a certain number of people based on the average number of people per household within that census block. The number of homes and total population was then summed for each Spout Run sub-watershed. Using this method, 786 homes and 1897 people were estimated within the Spout Run watershed (Table 5-2). Figure 5-3 shows the population density within the Spout Run watershed. Human populations within the watershed are generally centered around the Town of Boyce, and to a lesser degree around the community of Millwood and major transportation arteries.
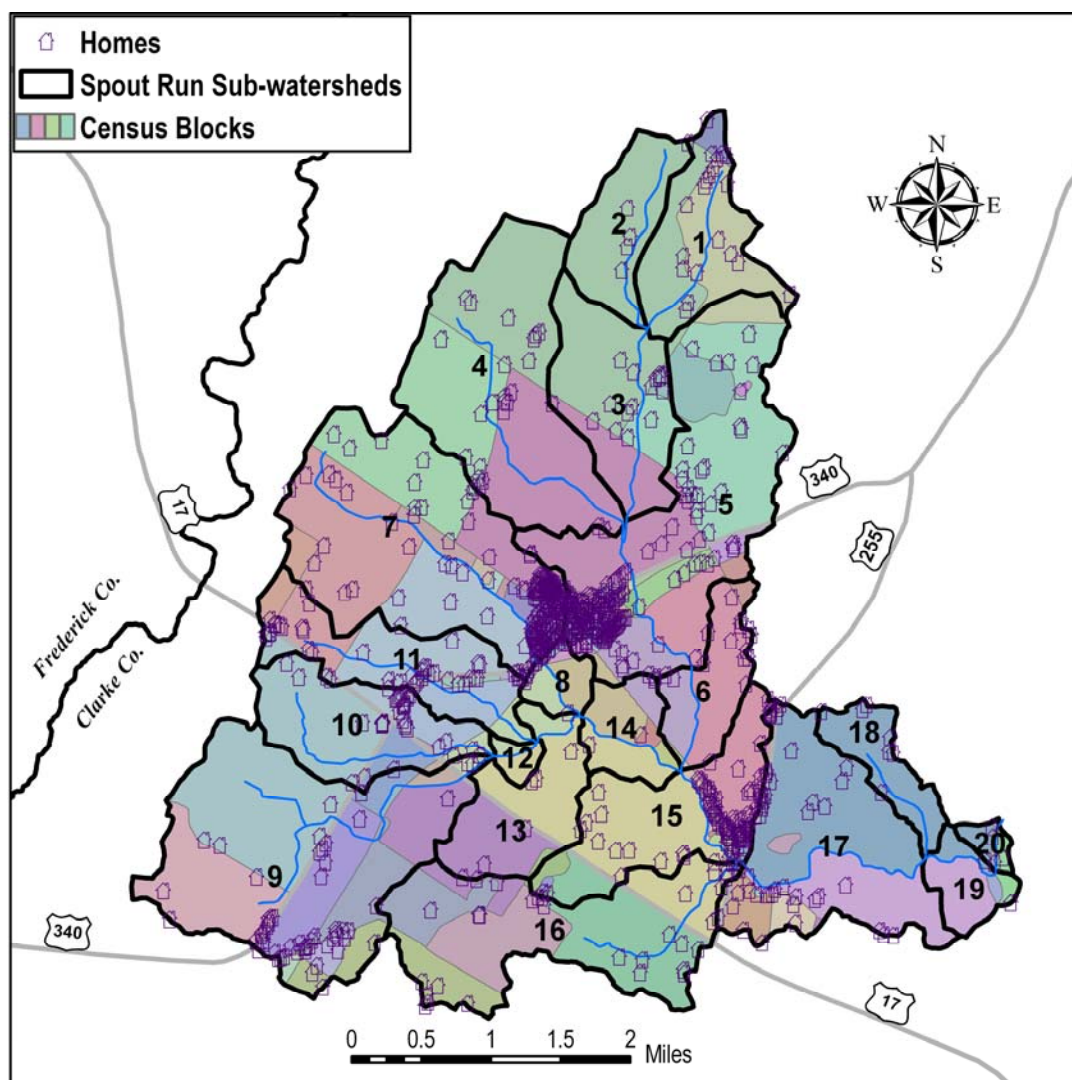
Figure 5-2. Homes and Census Blocks within the Spout Run Watershed.

Table 5-2. Estimated Human Population in the Spout Run Watershed.

Sub-watershed	# of Homes	Population	Average Occupancy Rate
1	21	55	2.6
2	4	9	2.3
3	16	44	2.8
4	23	52	2.3
5	204	492	2.4
6	11	28	2.5
7	181	487	2.7
8	6	17	2.8

9	56	132	2.4
10	32	74	2.3
11	42	104	2.5
12	0	0	0.0
13	7	12	1.7
14	3	6	2.0
15	94	213	2.3
16	29	54	1.9
17	44	93	2.1
18	7	13	1.9
19	1	2	2.0
20	5	10	2.0
Total	**786**	**1897**	
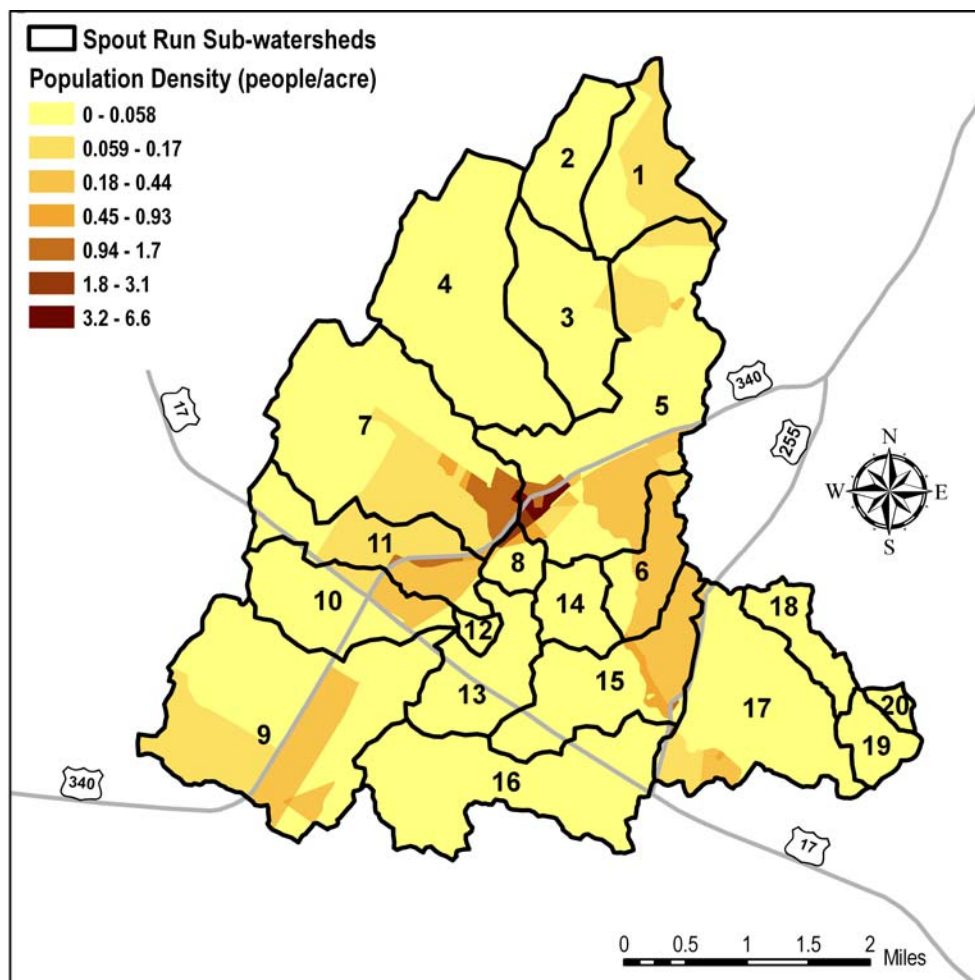
Figure 5-3. Population Density in the Spout Run Watershed.

5.2.1. Centralized Sewage Treatment

Sewer service is available for a portion of the Spout Run watershed. Figure 5-4 shows these areas, which include the town of Boyce, the community of Millwood, the area along Rt. 723 north of Millwood, and the area at the intersection of Rt. 17 and Rt. 340. Homes within these areas were assumed to have connections to centralized sewage treatment at the Boyce STP. The bacteria load from these homes is accounted for in the Boyce STP discharge. The remaining homes not within the sewer service area were assumed to have on-site treatment (i.e., septic systems) or no treatment (see Section 5.2.2). Table 5-3 shows the breakdown of homes within and outside of the sewer service areas. A total of 362 homes and an estimated population of 905 people are served by centralized sewage treatment. This represents 46% of homes and 48% of the population in the Spout Run watershed. A slightly higher percentage of homes (54%) are outside of the sewer service area and must have on-site treatment.
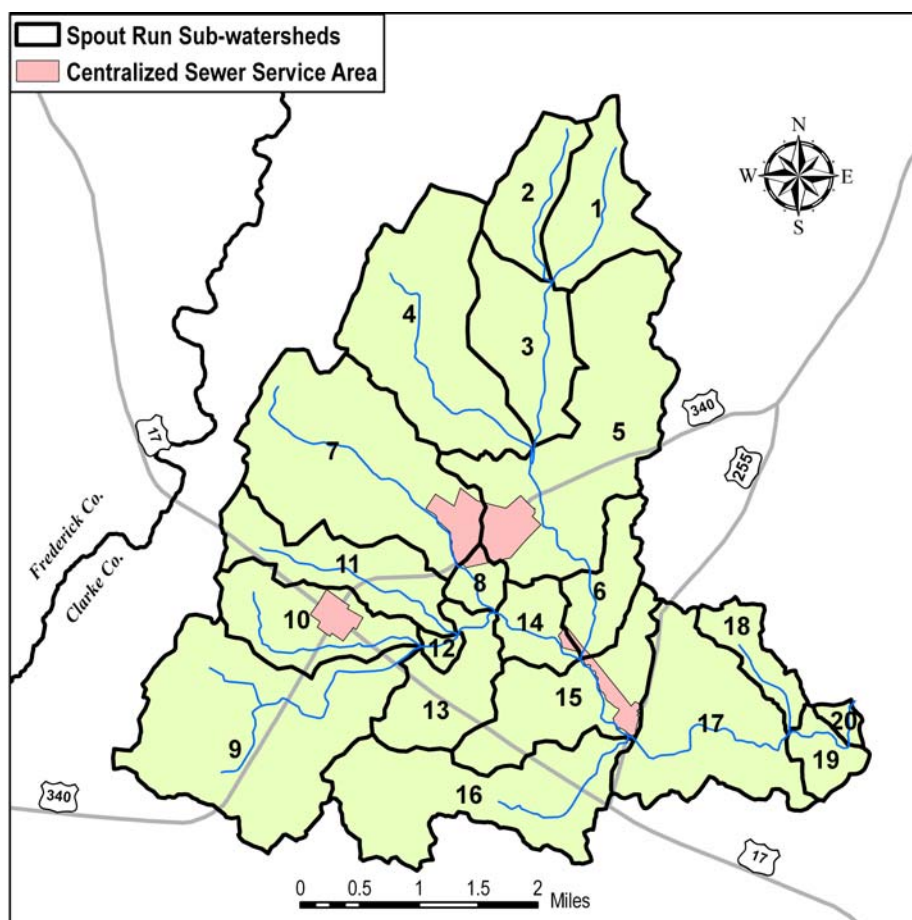
Figure 5-4. Sewer Service Areas within the Spout Run Watershed.

Table 5-3. **Homes and Human Population within the Spout Run Watershed on Centralized Sewer Service Versus On-site Treatment.**

Sub-watershed	Centralized Sewer System		On-site Treatment	
	Homes	**Population**	**Homes**	**Population**
1	0	0	21	55
2	0	0	4	9
3	0	0	16	44
4	0	0	23	52
5	145	339	59	153
6	0	0	11	28
7	141	394	40	93
8	4	13	2	4
9	0	0	56	132
10	12	28	20	46
11	0	0	42	104
12	0	0	0	0
13	0	0	7	12
14	0	0	3	6
15	60	131	34	82
16	0	0	29	54
17	0	0	44	93
18	0	0	7	13
19	0	0	1	2
20	0	0	5	10
Total	**362**	**905**	**424**	**992**

5.2.2. Straight Pipes

A portion of the homes that are not in the sewer service area may have the potential to have straight pipes. Straight pipes are illicit discharges of untreated sewage directly to surface waters. There is a potential for straight pipes in areas with very old homes located close to streams. At the time these homes were built, discharge of waste to the nearby stream may have been standard practice. If these homes have not been updated in several decades and appropriate waste treatment installed, some straight pipes may still exist.

To estimate the number of potential straight pipes in the Spout Run watershed, 2000 census data were consulted. Within the census block groups that encompass the Spout Run watershed, 2.2% of homes were reported as having incomplete plumbing facilities. This is an indication that these homes may have straight pipes. When the same percentage is applied to homes in the Spout Run watershed, 18 homes are estimated as having straight pipes. To identify the likely location of

these straight pipes in the Spout Run watershed, the closest 18 homes to perennial streams were identified from a geographic information system (GIS). Table 5-4 shows the estimated number of straight pipes in each sub-watershed.

Fecal coliform loading from these straight pipes was calculated based on the average occupancy rate for each sub-watershed, a septic waste flow of 70 gal/person/day (Metcalf and Eddy, 1991), and a fecal coliform concentration of 10^5 cfu/100ml (Metcalf and Eddy, 1991). Fecal coliform loadings from straight pipes, unlike failing septic systems, are discharged directly to surface waters and do not need rainfall events to transport bacteria to the stream. The fecal coliform loading from straight pipes in the Spout Run watershed was estimated at 3.99 x 10^{12} cfu/yr (Table 5-5).

Table 5-4. Estimated Number of Straight Pipes in the Spout Run Watershed.

Sub-watershed	Straight Pipes
1	1
2	1
3	0
4	0
5	2
6	0
7	3
8	0
9	0
10	1
11	1
12	0
13	0
14	0
15	3
16	2
17	2
18	0
19	0
20	2
Total	18

Table 5-5. Fecal Coliform Loading from Straight Pipes in the Spout Run Watershed.

Sub-watershed	Straight Pipes	Average Occupancy Rate	Septic Flow (gal/person/d)	Fecal Coliform Conc. (cfu/100ml)	Daily Fecal Coliform Loading	Annual Fecal Coliform Loading
1	1	2.6	70	1.00E+05	6.94E+08	2.53E+11
2	1	2.3	70	1.00E+05	5.96E+08	2.18E+11
3	0	2.8	70	1.00E+05	0.00E+00	0.00E+00
4	0	2.3	70	1.00E+05	0.00E+00	0.00E+00
5	2	2.4	70	1.00E+05	1.28E+09	4.66E+11
6	0	2.5	70	1.00E+05	0.00E+00	0.00E+00
7	3	2.7	70	1.00E+05	2.14E+09	7.81E+11
8	0	2.8	70	1.00E+05	0.00E+00	0.00E+00
9	0	2.4	70	1.00E+05	0.00E+00	0.00E+00
10	1	2.3	70	1.00E+05	6.13E+08	2.24E+11
11	1	2.5	70	1.00E+05	6.56E+08	2.39E+11
12	0	0.0	70	1.00E+05	0.00E+00	0.00E+00
13	0	1.7	70	1.00E+05	0.00E+00	0.00E+00
14	0	2.0	70	1.00E+05	0.00E+00	0.00E+00
15	3	2.3	70	1.00E+05	1.80E+09	6.57E+11
16	2	1.9	70	1.00E+05	9.87E+08	3.60E+11
17	2	2.1	70	1.00E+05	1.12E+09	4.09E+11
18	0	1.9	70	1.00E+05	0.00E+00	0.00E+00
19	0	2.0	70	1.00E+05	0.00E+00	0.00E+00
20	2	2.0	70	1.00E+05	1.06E+09	3.87E+11
Total	**18**				**1.09E+10**	**3.99E+12**

5.2.3. Failing Septic Systems

A total of 424 homes within the Spout Run watershed were identified as having on-site treatment (Table 5-3). These include the 18 estimated straight pipes (see Section 5.2.2) and 406 estimated septic systems. A portion of these systems may be failing. Septic system failure can be evidenced by the rise of effluent to the soil surface. Under these conditions the waste is not filtered through the soil matrix, so the waste is not treated and bacteria are not removed. Surface runoff can then transport the effluent containing fecal coliform to receiving waters.

The number of failing septic systems in the watershed was estimated from the age of homes and standard failure rates for septic systems of that age. The 406 homes with septic systems were broken into three age categories (prior to 1970, 1970-1989, or after 1989) in order to assess potential bacteria contributions. Houses were divided into age categories based on 2000 census block group data. Within each census block group, the percentage of homes within each age

category was calculated. These percentages were then applied to the homes in each sub-watershed based on the block group that had the greatest coverage of the sub-watershed. For the watershed as a whole, approximately 57% of houses were built before 1970, 24% were built between 1970 and 1989, and 18% were built after 1989 (Table 5-6).

Based on information from waste treatment experts, other nearby water quality studies, and local health department experts, septic system failure rates for houses pre-1970, 1970-1989, and post-1989 were assumed to be 35%, 20%, and 3%, respectively. Based on these failure rates, there is an estimated 99 failing septic systems in the Spout Run watershed (Table 5-6).

Table 5-6. Estimated Number of Failing Septic Systems in the Spout Run Watershed.

Sub-watershed	Houses per Age Category			Failure rate			Failing Systems			
	Pre 1970	1970-1989	Post 1989	Pre 1970	1970-1989	Post 1989	Pre 1970	1970-1989	Post 1989	Total
1	11	5	4	0.35	0.2	0.03	4	1	0	5
2	1	1	1	0.35	0.2	0.03	0	0	0	0
3	9	4	3	0.35	0.2	0.03	3	1	0	4
4	14	5	4	0.35	0.2	0.03	5	1	0	6
5	33	13	11	0.35	0.2	0.03	12	3	0	15
6	7	2	2	0.35	0.2	0.03	2	1	0	3
7	21	9	7	0.35	0.2	0.03	7	2	0	9
8	1	1	0	0.35	0.2	0.03	0	0	0	0
9	33	13	10	0.35	0.2	0.03	12	3	0	15
10	11	4	4	0.35	0.2	0.03	4	1	0	5
11	24	10	7	0.35	0.2	0.03	8	2	0	10
12	0	0	0	0.35	0.2	0.03	0	0	0	0
13	4	2	1	0.35	0.2	0.03	1	0	0	1
14	2	1	0	0.35	0.2	0.03	1	0	0	1
15	17	8	6	0.35	0.2	0.03	6	2	0	8
16	15	7	5	0.35	0.2	0.03	5	1	0	6
17	24	10	8	0.35	0.2	0.03	8	2	0	10
18	4	2	1	0.35	0.2	0.03	1	0	0	1
19	1	0	0	0.35	0.2	0.03	0	0	0	0
20	1	1	1	0.35	0.2	0.03	0	0	0	0
Subtotal	233	98	75				79	20	0	99
Total	406						99			

Daily total fecal coliform load to the land surface from a failing septic system in a particular sub-watershed was determined from the average occupancy rate for that sub-watershed (Table 5-2), a

typical septic waste flow of 70 gal/person/day (Metcalf and Eddy, 1991), and a typical fecal coliform concentration in septic waste of 10^5 cfu/100ml (Metcalf and Eddy, 1991). Based on these estimates, a daily fecal coliform load of 2.26 x 10^{13} cfu/yr is delivered to the land surface from failing septic systems in the Spout Run watershed (Table 5-7). Some portion of this load is then available for washoff and may contribute to instream fecal coliform loads.

Table 5-7. Fecal Coliform Loading to the Land Surface from Failing Septic Systems in the Spout Run Watershed.

Sub-watershed	Failing Septic Systems	Average Occupancy Rate	Septic Flow (gal/person/d)	Fecal Coliform Conc. (cfu/100ml)	Daily Fecal Coliform Loading	Annual Fecal Coliform Loading
1	5	2.6	70	1.00E+05	3.47E+09	1.27E+12
2	0	2.3	70	1.00E+05	0.00E+00	0.00E+00
3	4	2.8	70	1.00E+05	2.91E+09	1.06E+12
4	6	2.3	70	1.00E+05	3.59E+09	1.31E+12
5	15	2.4	70	1.00E+05	9.58E+09	3.50E+12
6	3	2.5	70	1.00E+05	2.02E+09	7.38E+11
7	9	2.7	70	1.00E+05	6.42E+09	2.34E+12
8	0	2.8	70	1.00E+05	0.00E+00	0.00E+00
9	15	2.4	70	1.00E+05	9.37E+09	3.42E+12
10	5	2.3	70	1.00E+05	3.06E+09	1.12E+12
11	10	2.5	70	1.00E+05	6.56E+09	2.39E+12
12	0	0.0	70	1.00E+05	0.00E+00	0.00E+00
13	1	1.7	70	1.00E+05	4.54E+08	1.66E+11
14	1	2.0	70	1.00E+05	5.30E+08	1.93E+11
15	8	2.3	70	1.00E+05	4.80E+09	1.75E+12
16	6	1.9	70	1.00E+05	2.96E+09	1.08E+12
17	10	2.1	70	1.00E+05	5.60E+09	2.04E+12
18	1	1.9	70	1.00E+05	4.92E+08	1.80E+11
19	0	2.0	70	1.00E+05	0.00E+00	0.00E+00
20	0	2.0	70	1.00E+05	0.00E+00	0.00E+00
Total	**99**				**6.18E+10**	**2.26E+13**

5.2.4. Biosolids

In the Spout Run watershed, there are 2264 acres permitted for biosolids application, which represents 16.5% of the land area in the Spout Run drainage. Individual permitted fields are shown in Figure 5-5. Within the last 5 years (2004-2008), biosolids were applied to 766 of these

acres (34% of permitted area and only 5.6% of the watershed). On these fields, application rates have ranged up to 23 dry tons/acre over the past 5 years (Figure 5-6).
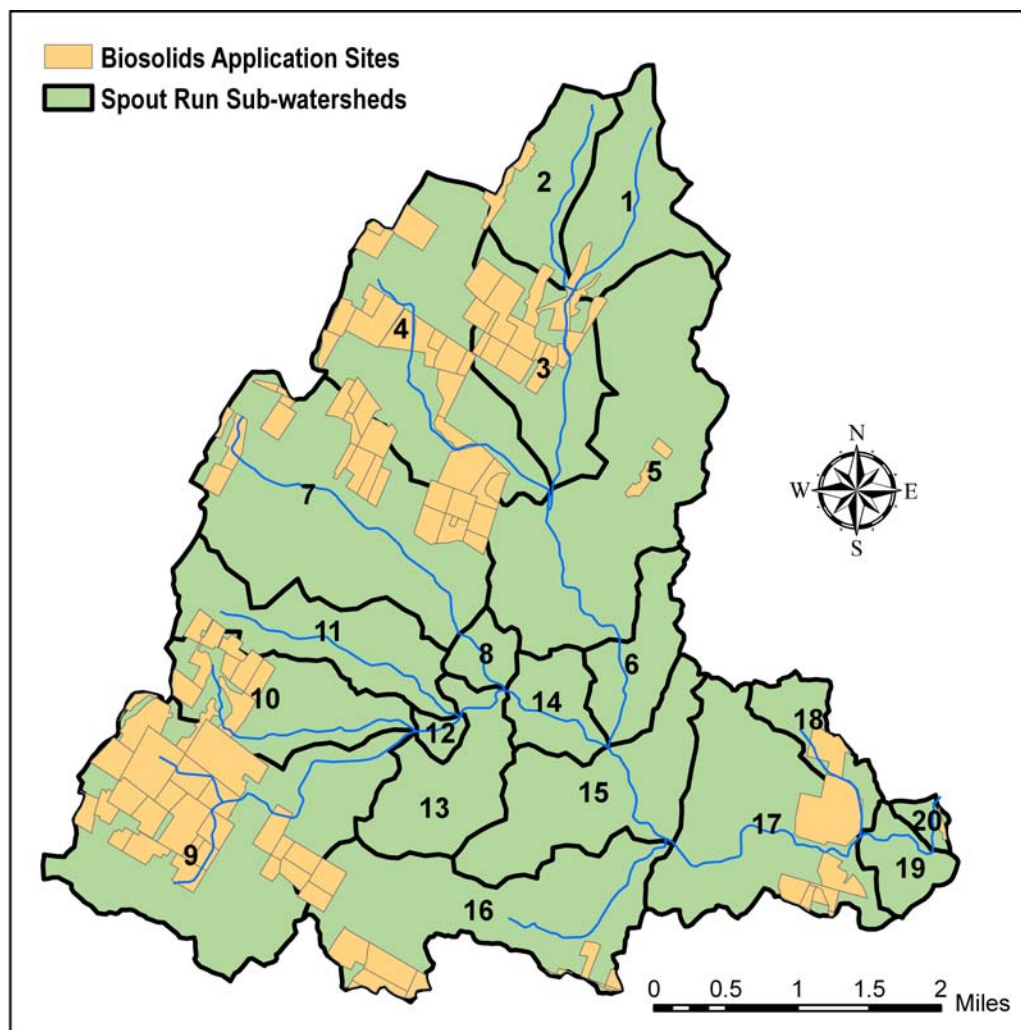
Figure 5-5. Permitted Biosolids Application Sites in the Spout Run Watershed.
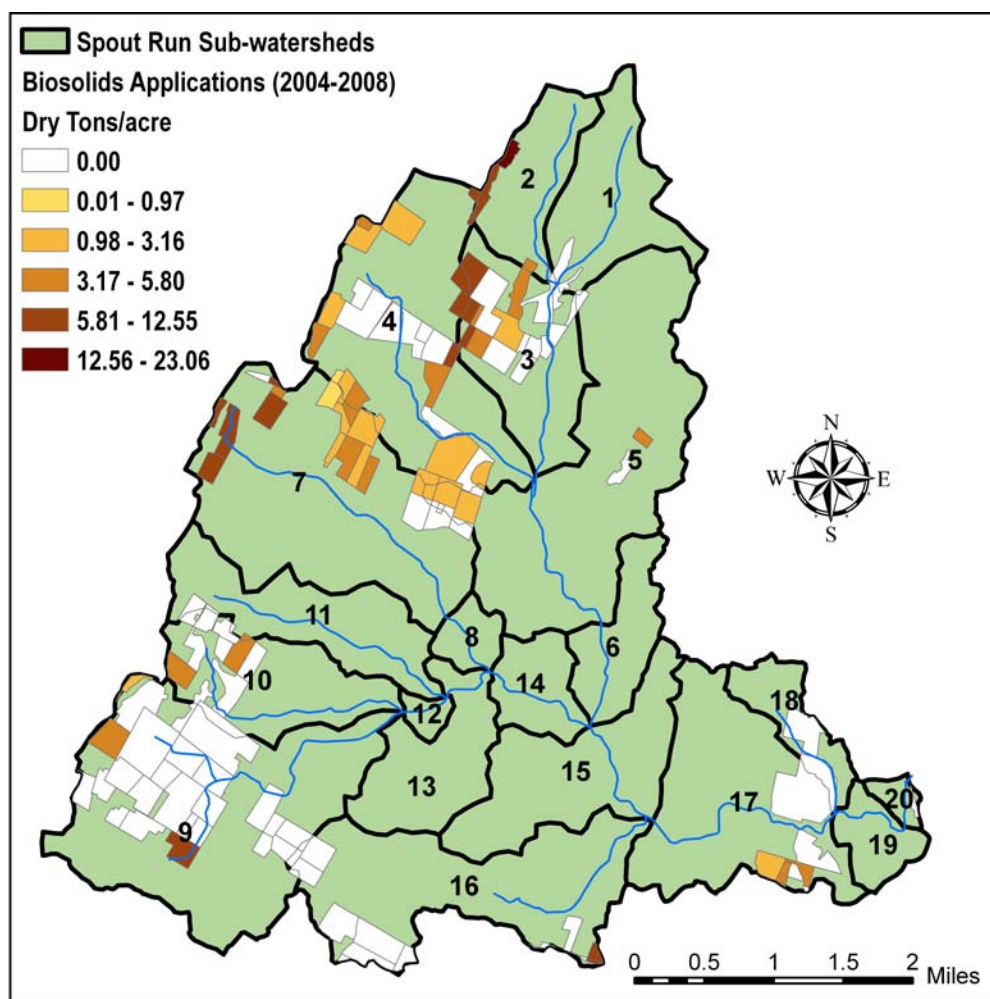
Figure 5-6. Biosolids Applications from 2004-2008 in the Spout Run Watershed.

Table 5-8 shows the amount of biosolids applied in each Spout Run sub-watershed. Ten of the 20 sub-watersheds received no biosolids from 2004-2008. The remaining 10 sub-watersheds received 3520 dry tons over the past 5 years. On average, this represented 4.59 dry tons/acre or 0.92 dry tons/acre/yr.

The concentration of fecal coliform in applied biosolids can be highly variable and is dependent upon the sludge treatment, stabilization, and handling processes. A land applied Class B biosolid must have fecal coliform concentrations less than $2x10^6$ cfu/g (USEPA, 2006), but concentrations are commonly orders of magnitude lower. Within the Spout Run watershed, the majority of biosolids applied comes from the Blue Plains Wastewater Treatment Plant in

Washington, D.C., so fecal coliform concentrations from this facility were used to characterize the biosolids applied in the Spout Run watershed. Typical fecal coliform concentrations in biosolids from this facility are 100,000 cfu/g (Chris Peot, DC Water and Sewer Authority, personal communication). Based on this concentration and average annual biosolid application rates, the Spout Run watershed receives a fecal coliform loading of approximately 6.39×10^{13} cfu/yr.

Table 5-8. Biosolids Applications and Fecal Coliform Loadings in the Spout Run Watershed.

Sub-watershed	Acres Permitted	Acres Applied (2004-2008)	Dry Tons Applied (2004-2008)	Dry Tons/acre (2004-2008)	Dry Tons/acre/ yr	Fecal Coliform Conc. (cfu/g)	Fecal Coliform Load (cfu/yr)
1	18	0	0	0.00	0.00	1.00E+05	0.00E+00
2	28	27	397	14.95	2.99	1.00E+05	7.21E+12
3	239	97	468	4.80	0.96	1.00E+05	8.48E+12
4	430	253	887	3.50	0.70	1.00E+05	1.61E+13
5	79	51	150	2.92	0.58	1.00E+05	2.72E+12
6	0	0	0	0.00	0.00	1.00E+05	0.00E+00
7	244	193	928	4.80	0.96	1.00E+05	1.68E+13
8	0	0	0	0.00	0.00	1.00E+05	0.00E+00
9	647	60	347	5.79	1.16	1.00E+05	6.29E+12
10	166	40	139	3.51	0.70	1.00E+05	2.53E+12
11	13	2	6	3.45	0.69	1.00E+05	1.06E+11
12	0	0	0	0.00	0.00	1.00E+05	0.00E+00
13	0	0	0	0.00	0.00	1.00E+05	0.00E+00
14	0	0	0	0.00	0.00	1.00E+05	0.00E+00
15	0	0	0	0.00	0.00	1.00E+05	0.00E+00
16	171	7	71	10.47	2.09	1.00E+05	1.29E+12
17	159	36	127	3.57	0.71	1.00E+05	2.30E+12
18	65	0	0	0.00	0.00	1.00E+05	0.00E+00
19	0	0	0	0.00	0.00	1.00E+05	0.00E+00
20	4	0	0	0.00	0.00	1.00E+05	0.00E+00
Total	2264	766	3520	4.59	0.92		6.39E+13

This annual fecal coliform loading, of course, is not continuous throughout the year. Biosolids application records were reviewed to determine the typical timings of biosolid applications. Table 5-9 and Figure 5-7 show the seasonal timing of biosolids applications over the past 5 years. In general, applications increased throughout the summer and decreased in the fall. No applications were conducted during the winter months of January, February, or March. July

received the highest loading at 23% of the annual load, followed by November with 18% of the annual load. The monthly percentages of annual loads were used in HSPF modeling to apportion the annual fecal coliform load from biosolids.

Table 5-9. Timing of Biosolids Applications within the Spout Run Watershed.

Month	Dry Tons Applied	% of Total
Jan	0	0%
Feb	0	0%
Mar	0	0%
Apr	71	2%
May	274	8%
Jun	564	16%
Jul	800	23%
Aug	382	11%
Sep	392	11%
Oct	238	7%
Nov	629	18%
Dec	170	5%
Total	**3520**	**100%**
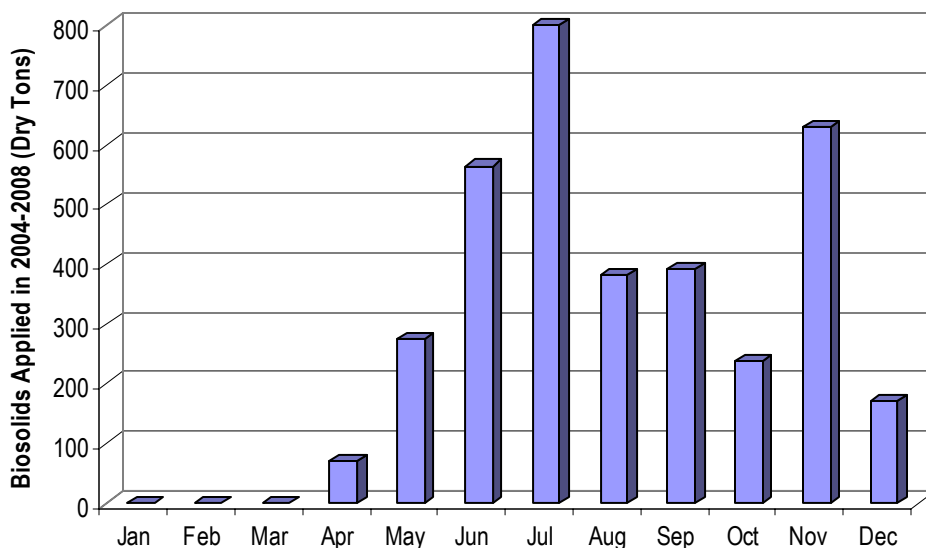
Figure 5-7. Monthly Biosolids Applications in the Spout Run Watershed.

5.3. PETS

The number of pets in the Spout Run watershed was estimated based on the number of homes and pet owner statistics from the American Veterinary Medical Association (AVMA, 2007). According to the AVMA, 37.2% of households own dogs and 32.4% of households own cats. Those households that own dogs have on average 1.7 dogs, and those households that own cats have on average 2.2 cats. Using these statistics, the estimated pet population in the Spout Run watershed is 497 dogs and 560 cats (Table 5-10). Using a fecal coliform production rate of 1.85 x 10^9 cfu/day for dogs and 2.98 x 10^8 cfu/day for cats (Weiskel *et al.*, 1996; Mara and Oragui, 1981), pets in the Spout Run watershed produce an estimated fecal coliform load of 3.01 x 10^{14} cfu/yr (Table 5-10). This load is deposited on the land surface in residential areas and is available for washoff and transport to surface waters.

Table 5-10. Fecal Coliform Loading from Pets in the Spout Run Watershed.

Sub-watershed	Households	Dogs		Cats		Daily Fecal Coliform Loading (cfu/d)	Annual Fecal Coliform Loading (cfu/yr)
		# of Animals	Fecal Production Rate Per Animal (cfu/d)	# of Animals	Fecal Production Rate Per Animal (cfu/d)		
1	21	13	1.85E+09	15	2.98E+08	2.90E+10	1.06E+13
2	4	3	1.85E+09	3	2.98E+08	5.53E+09	2.02E+12
3	16	10	1.85E+09	11	2.98E+08	2.21E+10	8.07E+12
4	23	15	1.85E+09	16	2.98E+08	3.18E+10	1.16E+13
5	204	129	1.85E+09	145	2.98E+08	2.82E+11	1.03E+14
6	11	7	1.85E+09	8	2.98E+08	1.52E+10	5.55E+12
7	181	114	1.85E+09	129	2.98E+08	2.50E+11	9.13E+13
8	6	4	1.85E+09	4	2.98E+08	8.29E+09	3.03E+12
9	56	35	1.85E+09	40	2.98E+08	7.74E+10	2.82E+13
10	32	20	1.85E+09	23	2.98E+08	4.42E+10	1.61E+13
11	42	27	1.85E+09	30	2.98E+08	5.80E+10	2.12E+13
12	0	0	1.85E+09	0	2.98E+08	0.00E+00	0.00E+00
13	7	4	1.85E+09	5	2.98E+08	9.67E+09	3.53E+12
14	3	2	1.85E+09	2	2.98E+08	4.15E+09	1.51E+12
15	94	59	1.85E+09	67	2.98E+08	1.30E+11	4.74E+13
16	29	18	1.85E+09	21	2.98E+08	4.01E+10	1.46E+13
17	44	28	1.85E+09	31	2.98E+08	6.08E+10	2.22E+13
18	7	4	1.85E+09	5	2.98E+08	9.67E+09	3.53E+12
19	1	1	1.85E+09	1	2.98E+08	1.38E+09	5.04E+11
20	5	3	1.85E+09	4	2.98E+08	6.91E+09	2.52E+12
Total	**786**	**497**		**560**		**8.24E+11**	**3.01E+14**

5.4. LIVESTOCK

Fecal coliform in waste from livestock can be directly excreted to the stream, or it can be transported to the stream by surface runoff from animal waste deposited on pastures or applied to crop, pasture, and hay land. The number of beef cattle, horses, and sheep within the Spout Run watershed was estimated from 2008 (if available) or 2007 agricultural statistics data for Clarke County (USDA-NASS, 2007; USDA-NASS, 2008), information from VADEQ, VDACS, and input from local stakeholders. To determine the number of animals in each sub-watershed, the number of animals in Clarke County was weighted by the ratio of pasture land in each sub-watershed to the acreage of pasture in Clarke County. Table 5-11 shows the estimated number of livestock within each Spout Run sub-watershed.

Table 5-11. Livestock Population Estimates in the Spout Run Watershed.

Sub-watershed	Pasture Acreage	Estimated Livestock Population				
		Beef Cattle	Dairy Cows	Horses	Sheep	Poultry
1	229	66	0	12	7	1
2	183	52	0	10	5	2
3	311	89	0	17	9	3
4	840	240	0	245[a]	24	4
5	1018	291	0	55	29	5
6	227	65	0	12	6	6
7	1179	337	0	63	34	7
8	46	13	0	2	1	8
9	1351	386	0	72	38	9
10	396	113	0	21	11	10
11	400	114	0	21	11	11
12	24	7	0	1	1	12
13	348	99	0	19	10	13
14	166	48	0	9	5	14
15	378	108	0	20	11	15
16	690	197	500[b]	37	20	16
17	714	204	0	38	20	17
18	210	60	0	11	6	18
19	11	3	0	1	0	19
20	23	7	0	1	1	20
Total	8744	2499	0	667	249	Total

[a] Based on Local Steering Committee input, the number of horses in sub-watershed 4 was increased by 200 to account for a large horse farm in that sub-watershed.

[b] White Post Dairy is located directly on the Spout Run watershed border. Dairy cows at this facility are kept in confinement, and collected manure is land applied according to a permitted nutrient management plan.

5.4.1. Beef Cattle

The number of beef cattle in the Spout Run watershed was estimated from 2008 agriculture statistics data for Clarke County (USDA-NASS, 2008). To determine the number of beef cattle in each sub-watershed, the number of cattle in Clarke County was weighted by the ratio of pasture land in each sub-watershed to the acreage of pasture in Clarke County. Based on this weighting, 2499 beef cattle were estimated in the Spout Run watershed. With each beef cow producing approximately 4.46 x 10^{10} fecal coliforms per day (ASAE, 1998), beef cattle within Spout Run produce an estimated annual load of 4.07 x 10^{16} fecal coliforms (Table 5-12). This load is deposited either directly onto pasture as animals are grazing or directly into perennial streams while cattle are wading. Beef cattle within the watershed were assumed to not be kept in confinement. Bacterial loads to the pasture land surface are available for washoff and transport to surface waters during precipitation events. The load that is deposited while cattle are wading in perennial streams directly affects instream bacterial loads and concentrations.

Table 5-12. Fecal Coliform Loading to the Land Surface and Perennial Streams from Beef Cattle in the Spout Run Watershed.

Sub-watershed	Beef Cattle	Fecal Production Rate per Animal (cfu/d)	Daily Fecal Coliform Loading (cfu/d)	Annual Fecal Coliform Loading (cfu/yr)
1	66	4.46E+10	2.94E+12	1.07E+15
2	52	4.46E+10	2.32E+12	8.47E+14
3	89	4.46E+10	3.97E+12	1.45E+15
4	240	4.46E+10	1.07E+13	3.91E+15
5	291	4.46E+10	1.30E+13	4.74E+15
6	65	4.46E+10	2.90E+12	1.06E+15
7	337	4.46E+10	1.50E+13	5.49E+15
8	13	4.46E+10	5.80E+11	2.12E+14
9	386	4.46E+10	1.72E+13	6.28E+15
10	113	4.46E+10	5.04E+12	1.84E+15
11	114	4.46E+10	5.08E+12	1.86E+15
12	7	4.46E+10	3.12E+11	1.14E+14
13	99	4.46E+10	4.42E+12	1.61E+15
14	48	4.46E+10	2.14E+12	7.81E+14
15	108	4.46E+10	4.82E+12	1.76E+15
16	197	4.46E+10	8.79E+12	3.21E+15
17	204	4.46E+10	9.10E+12	3.32E+15
18	60	4.46E+10	2.68E+12	9.77E+14
19	3	4.46E+10	1.34E+11	4.88E+13
20	7	4.46E+10	3.12E+11	1.14E+14
Total	**2499**		**1.11E+14**	**4.07E+16**

To determine the percentage of the bacterial load from beef cattle that is deposited directly in the stream versus on the land surface, the amount of pasture with stream access was determined using aerial imagery. Figure 5-8 shows the pasture areas in Spout Run where livestock have direct access to perennial streams. Throughout the watershed, livestock on 1083 acres of pasture have access to 5.29 miles of perennial streams (Table 5-13). This represents 38% of the 14 miles of total perennial stream length in the watershed and 12% of pasture within the watershed. Multiplying the beef cattle in each sub-watershed by the ratio of pasture with stream access to total pasture, a total of 310 beef cattle were estimated to have perennial stream access.

For beef cattle that do not have stream access, all of the bacterial load produced is deposited on pasture. For those beef cattle that have stream access, the amount of bacterial load deposited on pasture and directly in the stream was determined by the percentage of time that the cattle spent wading. Estimates of the amount of time that beef cattle spend grazing and wading (Table 5-14) were based on a study of cattle stream access (VADCR, 2002) and revised according to Local Steering Committee input. Initial estimates from an average of three farms in the VADCR study were 0.5 hr/cow/day in the summer and 0.2 hr/cow/day in the winter. The Local Steering Committee commented that access hours in the summer were low compared to local knowledge, so the values in June-August were increased to 0.75 hr/cow/day. The Local Steering Committee also commented that access was very dependent upon shading, so access times were further modified by available tree cover in the riparian area. A geographic information system was used to determine the percentage tree cover within a 35-foot buffer of stream access areas. Sub-watersheds varied from 7% to 96% tree cover within stream access areas (Table 5-15). The ratio of tree cover within each sub-watershed to the average tree cover across sub-watersheds was used as a weighting factor to increase or decrease the amount of time spent in perennial streams by livestock. Using this weighting factor (Table 5-15) and monthly variations (Table 5-14) the amount of time cattle spend in stream was estimated for each month and sub-watershed (Table 5-16). Based on these estimates, fecal coliform contributions from livestock in stream were calculated.

Calibration of the water quality model revealed that initial estimates of direct deposits were too high, so cattle and wildlife direct deposits were reduced by 75% in order to obtain a successful calibration (see Section 7.7.2). Daily direct deposit loads were also adjusted based on cloud

cover data from the Winchester Regional Airport. Direct deposits were eliminated on overcast days with complete cloud cover. This provided additional day-to-day variability in direct deposit loads that was missing from monthly estimates. Table 5-17 shows the calibrated daily load of fecal coliform deposited by cattle directly in the stream. Based on the calibrated model, livestock access contributes an annual yearly load of 1.74×10^{13} fecal coliforms.
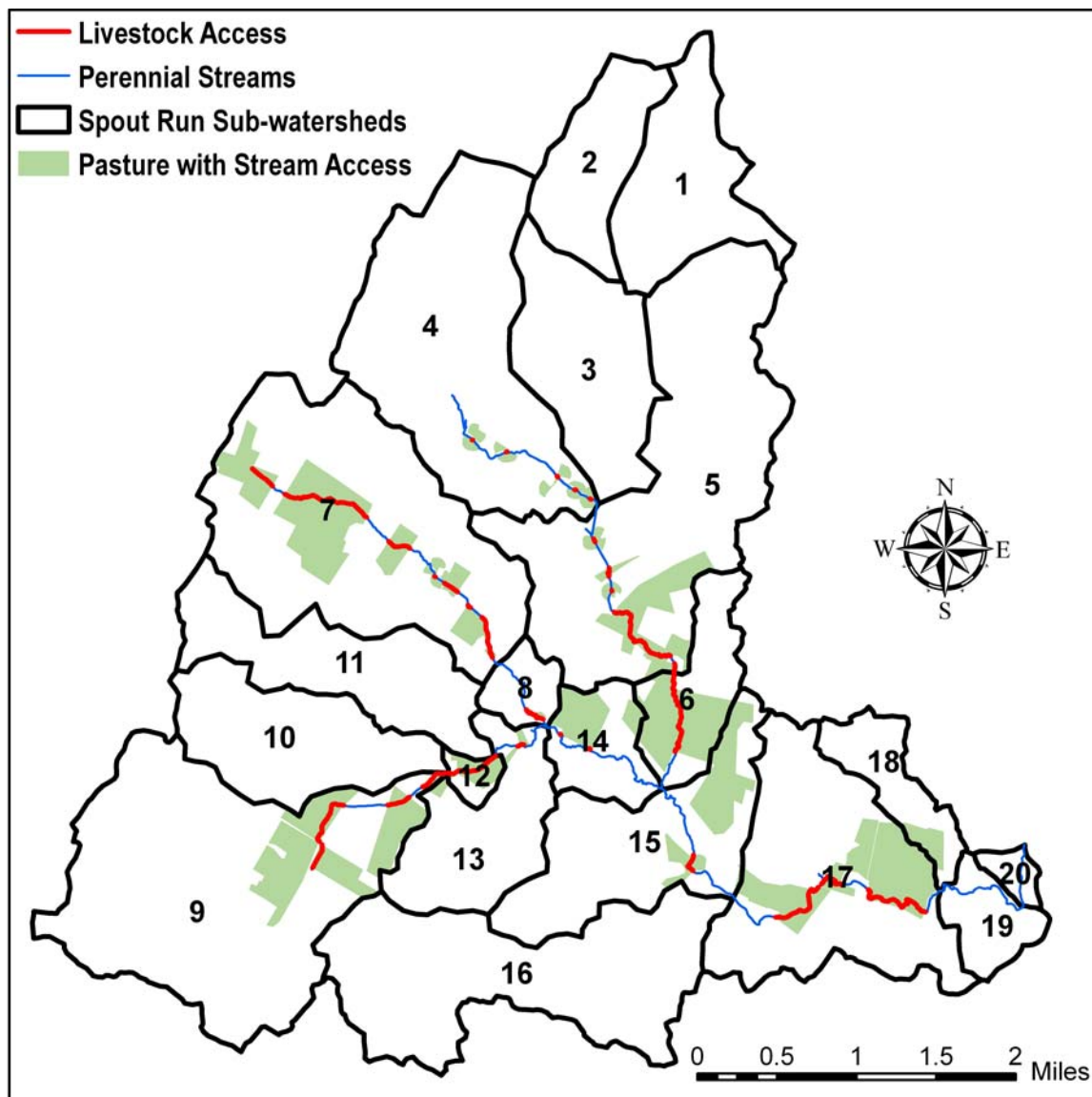
Figure 5-8. Perennial Stream Reaches with Livestock Access in the Spout Run Watershed.

Table 5-13. Livestock with Access to Perennial Streams in the Spout Run Watershed.

Sub-watershed	Total Pasture (acres)	Total Beef Cattle	Perennial Stream Access (miles)	Pasture with Stream Access (acres)	Percent of Pasture with Stream Access	Beef Cattle with Stream Access
1	229	66	0.00	0	0%	0
2	183	52	0.00	0	0%	0
3	311	89	0.00	0	0%	0
4	840	240	0.04	34	4%	10
5	1018	291	0.73	144	14%	41
6	227	65	0.58	144	63%	41
7	1179	337	1.45	147	12%	42
8	46	13	0.00	3	7%	1
9	1351	386	0.83	239	18%	68
10	396	113	0.00	0	0%	0
11	400	114	0.00	0	0%	0
12	24	7	0.30	24	100%	7
13	348	99	0.07	12	3%	3
14	166	48	0.02	73	44%	21
15	378	108	0.13	125	33%	36
16	690	197	0.00	0	0%	0
17	714	204	1.15	111	16%	32
18	210	60	0.00	28	13%	8
19	11	3	0.00	0	0%	0
20	23	7	0.00	0	0%	0
Total	**8744**	**2499**	**5.29**	**1083**	**12%**	**310**

Table 5-14. Daily Hours Spent by Beef Cattle on Pasture and in the Stream.

Month	Time Spent in Pasture (hr/d)	Time Spent In Stream (hr/d)
January	23.80	0.2
February	23.80	0.2
March	23.80	0.2
April	23.50	0.5
May	23.50	0.5
June	23.25	0.75
July	23.25	0.75
August	23.25	0.75
September	23.50	0.5
October	23.80	0.2
November	23.80	0.2
December	23.80	0.2

Table 5-15. Tree Cover within 35 Feet of Perennial Stream Access Areas.

Sub-watershed	Buffer Area (acres)	% Tree Cover	Weighting Factor
4	2.28	14.63%	0.30
5	15.96	19.51%	0.39
6	10.06	96.13%	1.94
7	24.69	6.98%	0.14
8	2.78	76.00%	1.53
9	15.35	10.14%	0.20
12	5.84	80.95%	1.63
13	1.45	92.31%	1.86
14	1.11	40.00%	0.81
15	2.56	80.43%	1.62
17	20.57	28.11%	0.57
	Average	49.56%	

Table 5-16. Time Spent in Stream by Livestock in the Spout Run Watershed (hr/d).

Sub-watershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.06	0.06	0.06	0.15	0.15	0.22	0.22	0.22	0.15	0.06	0.06	0.06
5	0.08	0.08	0.08	0.20	0.20	0.30	0.30	0.30	0.20	0.08	0.08	0.08
6	0.39	0.39	0.39	0.97	0.97	1.45	1.45	1.45	0.97	0.39	0.39	0.39
7	0.03	0.03	0.03	0.07	0.07	0.11	0.11	0.11	0.07	0.03	0.03	0.03
8	0.31	0.31	0.31	0.77	0.77	1.15	1.15	1.15	0.77	0.31	0.31	0.31
9	0.04	0.04	0.04	0.10	0.10	0.15	0.15	0.15	0.10	0.04	0.04	0.04
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.33	0.33	0.33	0.82	0.82	1.22	1.22	1.22	0.82	0.33	0.33	0.33
13	0.37	0.37	0.37	0.93	0.93	1.40	1.40	1.40	0.93	0.37	0.37	0.37
14	0.16	0.16	0.16	0.40	0.40	0.61	0.61	0.61	0.40	0.16	0.16	0.16
15	0.32	0.32	0.32	0.81	0.81	1.22	1.22	1.22	0.81	0.32	0.32	0.32
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.11	0.11	0.11	0.28	0.28	0.43	0.43	0.43	0.28	0.11	0.11	0.11
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 5-17. Instream Direct Deposit Loading of Fecal Coliform (#/d) from Beef Cattle in the Spout Run Watershed.

Sub-watershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4	2.74E+08	2.74E+08	2.74E+08	6.86E+08	6.86E+08	1.03E+09	1.03E+09	1.03E+09	6.86E+08	2.74E+08	2.74E+08	2.74E+08	6.79E+09
5	1.50E+09	1.50E+09	1.50E+09	3.75E+09	3.75E+09	5.62E+09	5.62E+09	5.62E+09	3.75E+09	1.50E+09	1.50E+09	1.50E+09	3.71E+10
6	1.32E+10	1.32E+10	1.32E+10	3.31E+10	3.31E+10	4.96E+10	4.96E+10	4.96E+10	3.31E+10	1.32E+10	1.32E+10	1.32E+10	3.27E+11
7	5.50E+08	5.50E+08	5.50E+08	1.37E+09	1.37E+09	2.06E+09	2.06E+09	2.06E+09	1.37E+09	5.50E+08	5.50E+08	5.50E+08	1.36E+10
8	1.42E+08	1.42E+08	1.42E+08	3.56E+08	3.56E+08	5.34E+08	5.34E+08	5.34E+08	3.56E+08	1.42E+08	1.42E+08	1.42E+08	3.53E+09
9	1.29E+09	1.29E+09	1.29E+09	3.23E+09	3.23E+09	4.85E+09	4.85E+09	4.85E+09	3.23E+09	1.29E+09	1.29E+09	1.29E+09	3.20E+10
10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
11	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
12	1.06E+09	1.06E+09	1.06E+09	2.66E+09	2.66E+09	3.98E+09	3.98E+09	3.98E+09	2.66E+09	1.06E+09	1.06E+09	1.06E+09	2.63E+10
13	5.19E+08	5.19E+08	5.19E+08	1.30E+09	1.30E+09	1.95E+09	1.95E+09	1.95E+09	1.30E+09	5.19E+08	5.19E+08	5.19E+08	1.28E+10
14	1.29E+09	1.29E+09	1.29E+09	3.22E+09	3.22E+09	4.83E+09	4.83E+09	4.83E+09	3.22E+09	1.29E+09	1.29E+09	1.29E+09	3.19E+10
15	1.12E+09	1.12E+09	1.12E+09	2.81E+09	2.81E+09	4.21E+09	4.21E+09	4.21E+09	2.81E+09	1.12E+09	1.12E+09	1.12E+09	2.78E+10
16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
17	2.11E+09	2.11E+09	2.11E+09	5.27E+09	5.27E+09	7.90E+09	7.90E+09	7.90E+09	5.27E+09	2.11E+09	2.11E+09	2.11E+09	5.22E+10
18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.76E+01
19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total (#/d)	**2.31E+10**	**2.31E+10**	**2.31E+10**	**5.77E+10**	**5.77E+10**	**8.66E+10**	**8.66E+10**	**8.66E+10**	**5.77E+10**	**2.31E+10**	**2.31E+10**	**2.31E+10**	**5.71E+11**
Days/mo.	**31**	**28**	**31**	**30**	**31**	**30**	**31**	**31**	**30**	**31**	**30**	**31**	
Total (#/mo.)	**7.16E+11**	**6.46E+11**	**7.16E+11**	**1.73E+12**	**1.79E+12**	**2.60E+12**	**2.68E+12**	**2.68E+12**	**1.73E+12**	**7.16E+11**	**6.92E+11**	**7.16E+11**	**1.74E+13**

5.4.2. Dairy Cows

The number of dairy cows in the Spout Run watershed was estimated based on information provided by VADEQ and VDACS. Based on VADEQ and VDACS records, there is only one dairy within the watershed. This dairy, the White Post Dairy, is permitted by VADEQ as a confined animal feeding operation (CAFO). Currently the dairy has approximately 500 milking cows. All of these cows are kept in confinement and manure is collected, stored in a lagoon, and land applied to cropland or hayland. To determine bacterial loadings, the dairy's nutrient management plan was consulted to identify fields used for manure application and maximum loadings approved for those fields. Many land application sites permitted under the White Post Dairy permit are outside of the watershed, but 263 acres are permitted within the Spout Run watershed (Figure 5-9). Assuming a fecal coliform concentration of 271,000 cfu/g in dry manure and 44,600 cfu/100ml in stored liquid manure (VADEQ, 2007b), land application sites receive a fecal coliform loading of 7.86×10^{14} cfu/yr (Table 5-18). Manure applications were modeled according to nutrient management plans, with application in the spring (April/May) and fall (October/November). Manure was applied to cropland as a first priority and then to hayland as a second priority if all cropland within a sub-watershed was already accounted for.
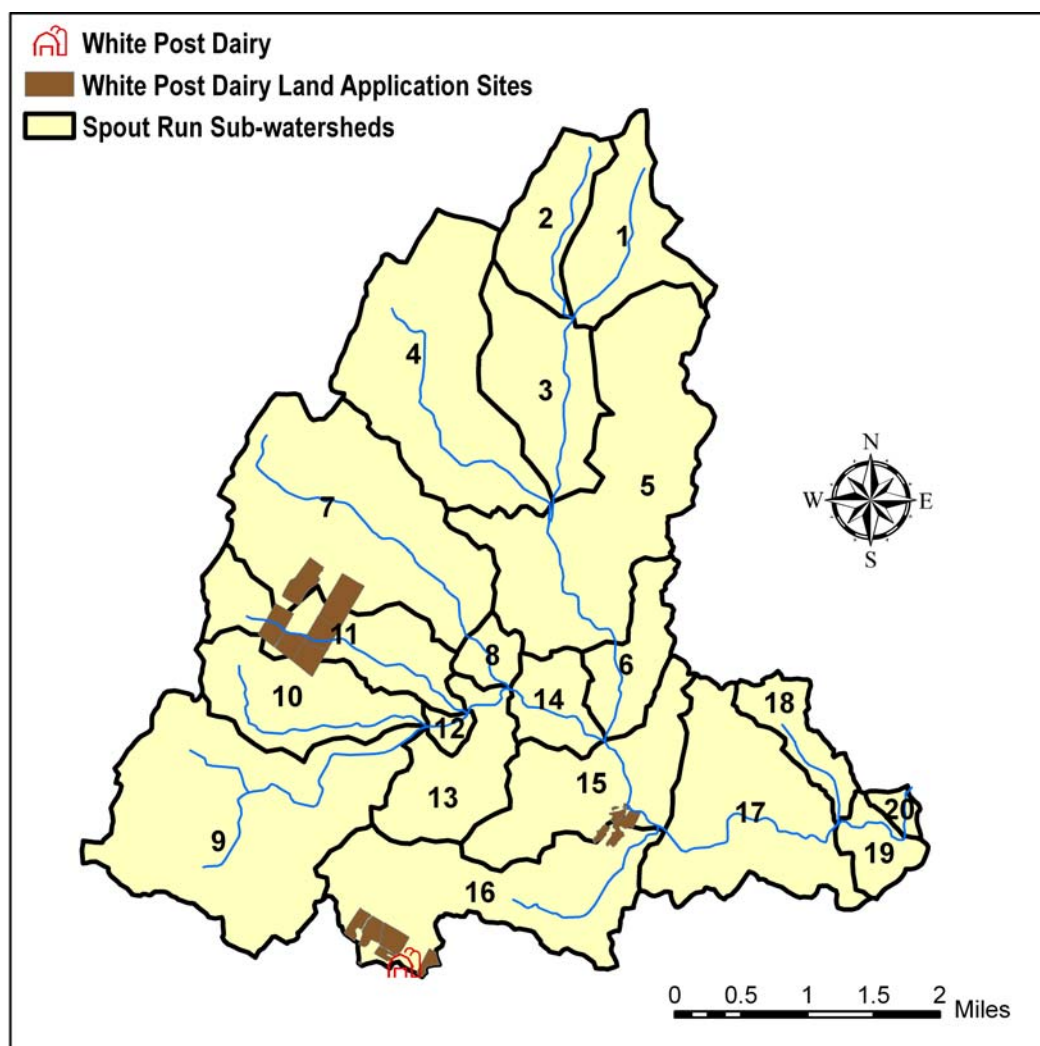
Figure 5-9. Land Application Sites Under White Post Dairy CAFO Permit.

Table 5-18. Fecal Coliform Loads from Land-Applied Dairy Manure in the Spout Run Watershed.

Sub-watershed	Acres	Fecal Load (cfu/yr)
7	63	1.55E+14
10	13	3.21E+13
11	97	2.38E+14
15	14	3.42E+13
16	76	3.27E+14
Total	**263**	**7.86E+14**

5.4.3. Horses

The number of horses in the Spout Run watershed was estimated from 2007 agriculture statistics data for Clarke County (USDA-NASS, 2007). To determine the number of horses in each sub-watershed, the number of horses in Clarke County was weighted by the ratio of pasture land in each sub-watershed to the acreage of pasture in Clarke County. In addition, the Local Steering Committee identified a large horse farm in sub-watershed 4 and suggested adding 200 horses to the estimate within that sub-watershed. Based on the weighting approach and input from the Local Steering Committee, 667 horses were estimated in the Spout Run watershed. With each horse producing approximately 5.15×10^{10} fecal coliforms per day (ASAE, 1998), horses within Spout Run produce an estimated annual load of 1.25×10^{16} fecal coliforms (Table 5-19). While some of this material is collected and stored for land application, Local Steering Committee input suggested that spreading of collected material occurred on a virtually continual basis. For this reason, horse manure was modeled as continually being deposited on pasture. This deposited load is then available for washoff and transport to surface waters during runoff events.

Table 5-19. Annual Fecal Coliform Loading from Horses in the Spout Run Watershed.

Sub-watershed	Number of Horses	Fecal Production Rate per Animal (cfu/d)	Daily Fecal Coliform Loading (cfu/d)	Annual Fecal Coliform Loading (cfu/yr)
1	12	5.15E+10	6.18E+11	2.26E+14
2	10	5.15E+10	5.15E+11	1.88E+14
3	17	5.15E+10	8.76E+11	3.20E+14
4	245	5.15E+10	1.26E+13	4.61E+15
5	55	5.15E+10	2.83E+12	1.03E+15
6	12	5.15E+10	6.18E+11	2.26E+14
7	63	5.15E+10	3.24E+12	1.18E+15
8	2	5.15E+10	1.03E+11	3.76E+13
9	72	5.15E+10	3.71E+12	1.35E+15
10	21	5.15E+10	1.08E+12	3.95E+14
11	21	5.15E+10	1.08E+12	3.95E+14
12	1	5.15E+10	5.15E+10	1.88E+13
13	19	5.15E+10	9.79E+11	3.57E+14
14	9	5.15E+10	4.64E+11	1.69E+14
15	20	5.15E+10	1.03E+12	3.76E+14
16	37	5.15E+10	1.91E+12	6.96E+14
17	38	5.15E+10	1.96E+12	7.14E+14
18	11	5.15E+10	5.67E+11	2.07E+14
19	1	5.15E+10	5.15E+10	1.88E+13
20	1	5.15E+10	5.15E+10	1.88E+13
Total	**667**		**3.44E+13**	**1.25E+16**

5.4.4. Sheep

The number of sheep in the Spout Run watershed was estimated from 2007 agriculture statistics data for Clarke County (USDA-NASS, 2007). To determine the number of sheep in each sub-watershed, the number of sheep in Clarke County was weighted by the ratio of pasture land in each sub-watershed to the acreage of pasture in Clarke County. Based on this weighting, 249 sheep were estimated in the Spout Run watershed. With each sheep producing approximately 1.96×10^{10} fecal coliforms per day (ASAE, 1998), sheep within Spout Run produce an estimated annual load of 1.78×10^{15} fecal coliforms (Table 5-20). Because sheep are not assumed to be confined in areas where manure is collected and stored, this load is deposited directly onto pasture and is available for washoff and transport to surface waters during precipitation events.

Table 5-20. Annual Fecal Coliform Loading from Sheep in the Spout Run Watershed.

Sub-watershed	Number of Sheep	Fecal Production Rate per Animal (cfu/d)	Daily Fecal Coliform Loading (cfu/d)	Annual Fecal Coliform Loading (cfu/yr)
1	7	1.96E+10	1.37E+11	5.01E+13
2	5	1.96E+10	9.80E+10	3.58E+13
3	9	1.96E+10	1.76E+11	6.44E+13
4	24	1.96E+10	4.70E+11	1.72E+14
5	29	1.96E+10	5.68E+11	2.07E+14
6	6	1.96E+10	1.18E+11	4.29E+13
7	34	1.96E+10	6.66E+11	2.43E+14
8	1	1.96E+10	1.96E+10	7.15E+12
9	38	1.96E+10	7.45E+11	2.72E+14
10	11	1.96E+10	2.16E+11	7.87E+13
11	11	1.96E+10	2.16E+11	7.87E+13
12	1	1.96E+10	1.96E+10	7.15E+12
13	10	1.96E+10	1.96E+11	7.15E+13
14	5	1.96E+10	9.80E+10	3.58E+13
15	11	1.96E+10	2.16E+11	7.87E+13
16	20	1.96E+10	3.92E+11	1.43E+14
17	20	1.96E+10	3.92E+11	1.43E+14
18	6	1.96E+10	1.18E+11	4.29E+13
19	0	1.96E+10	0.00E+00	0.00E+00
20	1	1.96E+10	1.96E+10	7.15E+12
Total	249		4.88E+12	1.78E+15

5.4.5. Poultry

VADEQ issues confined animal feeding operation (CAFO) permits for poultry facilities that contain more than 20,000 chickens or 11,000 turkeys. Based on VADEQ's database of CAFO permits, there are no permitted poultry facilities in the Spout Run watershed. VADEQ also maintains a database of poultry litter that is transferred from permitted facilities to other watersheds for land application. No poultry litter transfers into the Spout Run watershed were recorded in the database from 2004-2009. Based on this information, VADEQ estimated no bacterial load from poultry in the Spout Run watershed. This assumption was also confirmed by the Local Steering Committee.

5.4.6. Other Livestock

While additional livestock species, such as goats, pigs or llamas, may exist in the watershed, the numbers of these animals within the Spout Run watershed would be extremely small and have little impact on overall watershed-level bacteria loadings. For this reason, no other livestock were included in the Spout Run TMDL model. The Local Steering Committee confirmed this assumption.

5.5. WILDLIFE

Wildlife populations in the watershed were determined based on estimates of the available habitat for each species and the population density of animals within that habitat. Habitat descriptions and population density estimates were obtained from the TMDL developed for the neighboring Upper Opequon Creek watershed (VADEQ, 2004b) and information provided by VADGIF, the Local Steering Committee, and a deer population study in Clarke County (McShea *et al*., 2007). Based on these estimates and available land use in the watershed, populations were estimated for deer, raccoon, muskrat, beaver, geese, wood duck, and wild turkey (Table 5-21). For instance, muskrats were assumed to be found within 66 feet of streams or impoundments in forest and cropland. A geographic information system (GIS) was used to calculate the acreage of forest and cropland within 66 feet of perennial streams or lakes. This acreage was then multiplied by the population density of muskrats to obtain an estimate of the population in the

watershed. Table 5-22 shows final estimated populations for each wildlife species in each sub-watershed.

Table 5-21. Wildlife Habitat and Initial Population Estimates in the Spout Run Watershed.

Wildlife Type	Habitat	Acres of Habitat	Population Density (animals/ac-habitat)	Population (#)	Fecal Coliform Production Rate (cfu/animal/d)	Direct Deposition in Streams (%)
Deer	Entire Watershed	13711	0.093	1275	3.47E+08	0.0%
Raccoon	600 ft buffer around streams and impoundments	4545	0.07	318	1.13E+08	1.0%
Muskrat	66 ft buffer around streams and impoundments in forest and cropland	154	2.75	422	2.50E+07	2.5%
Beaver	300 ft buffer around main streams and impoundments in forest and pasture	2157	0.015	32	3.00E+05	50.0%
Geese - off season	300 ft buffer around main streams and impoundments	2227	0.078	175	7.99E+08	2.5%
Geese - in season	300 ft buffer around main streams and impoundments	2227	0.1092	244	7.99E+08	2.5%
Wood Duck - off season	300 ft buffer around main streams and impoundments	2227	0.0624	139	2.43E+09	2.5%
Wood Duck - in season	300 ft buffer around main streams and impoundments	2227	0.0936	208	2.43E+09	2.5%
Wild Turkey	Entire watershed except urban and residential	12586	0.01	125	9.30E+07	0.0%

Fecal coliform loads from wildlife were determined by multiplying the population of each wildlife species by the daily fecal production rates (VADEQ, 2004b). This fecal coliform load can be deposited directly into streams or on the land surface, where it is available for washoff and transport to surface waters during precipitation events. Fecal coliform from wildlife was distributed based on the wildlife habitat and habits of each species. For instance, fecal coliform from muskrats was assumed to be deposited in the stream 2.5% of the time, with the remaining load deposited on forest and cropland within 66 feet of streams and impoundments. Estimates of

the percentage of fecal coliform load deposited in the stream were made based on best professional judgment and were adjusted during calibration of the water quality model. Calibration of the water quality model revealed that initial estimates of direct deposits were too high, so cattle and wildlife direct deposits were reduced by 75% in order to obtain a successful calibration (see Section 7.7.2). Table 5-23 shows the calibrated annual fecal coliform loading to the land surface from wildlife. Ducks, geese, and deer accounted for the majority of fecal coliform loadings from wildlife in the Spout Run watershed. This was primarily due to the large population of deer in the watershed and the relatively high fecal coliform production rate by ducks and geese. Table 5-24 shows the calibrated daily load of fecal coliform deposited by wildlife directly in the stream. Wildlife direct deposit loads were dominated by geese and wood duck contributions.

Table 5-22. Wildlife Population Estimates in Spout Run Sub-Watersheds.

Sub-watershed	Deer	Raccoon	Muskrat	Beaver	Geese-off season	Geese-in season	Wood Duck-off season	Wood Duck-in season	Wild Turkey
1	51	15	60	1	8	11	6	10	5
2	38	13	10	1	8	11	6	9	4
3	61	18	32	2	10	14	8	12	6
4	122	31	13	3	16	23	13	20	13
5	150	17	10	2	9	12	7	11	14
6	32	7	29	1	4	6	3	5	3
7	140	39	14	4	20	28	16	24	14
8	12	5	16	1	3	4	2	3	1
9	160	45	16	4	24	33	19	28	16
10	57	24	13	2	13	18	11	16	5
11	58	21	10	2	12	17	9	14	5
12	5	3	10	0	2	3	2	2	1
13	47	5	9	1	3	4	2	3	5
14	24	8	21	1	5	7	4	6	2
15	70	8	41	1	5	7	4	6	7
16	105	20	31	2	11	15	9	13	10
17	97	21	30	2	11	15	9	13	10
18	23	9	17	1	6	8	4	7	2
19	18	6	26	1	3	5	3	4	2
20	5	3	14	0	2	3	2	2	0
Total	1275	318	422	32	175	244	139	208	125

Table 5-23. Annual Fecal Coliform Loading (cfu/yr) to the Land Surface from Wildlife in the Spout Run Watershed.

Sub-watershed	Deer	Raccoon	Muskrat	Beaver	Geese	Wood Duck	Wild Turkey
1	6.46E+12	6.19E+11	5.48E+11	1.10E+08	2.77E+12	7.09E+12	1.70E+11
2	4.81E+12	5.36E+11	9.13E+10	1.10E+08	2.77E+12	6.65E+12	1.36E+11
3	7.73E+12	7.42E+11	2.92E+11	2.19E+08	3.50E+12	8.86E+12	2.04E+11
4	1.55E+13	1.28E+12	1.19E+11	3.29E+08	5.68E+12	1.46E+13	4.41E+11
5	1.90E+13	7.01E+11	9.13E+10	2.19E+08	3.06E+12	7.98E+12	4.75E+11
6	4.05E+12	2.89E+11	2.65E+11	1.10E+08	1.46E+12	3.55E+12	1.02E+11
7	1.77E+13	1.61E+12	1.28E+11	4.38E+08	7.00E+12	1.77E+13	4.75E+11
8	1.52E+12	2.06E+11	1.46E+11	1.10E+08	1.02E+12	2.22E+12	3.39E+10
9	2.03E+13	1.86E+12	1.46E+11	4.38E+08	8.31E+12	2.08E+13	5.43E+11
10	7.22E+12	9.90E+11	1.19E+11	2.19E+08	4.52E+12	1.20E+13	1.70E+11
11	7.35E+12	8.66E+11	9.13E+10	2.19E+08	4.23E+12	1.02E+13	1.70E+11
12	6.33E+11	1.24E+11	9.13E+10	0.00E+00	7.29E+11	1.77E+12	3.39E+10
13	5.95E+12	2.06E+11	8.21E+10	1.10E+08	1.02E+12	2.22E+12	1.70E+11
14	3.04E+12	3.30E+11	1.92E+11	1.10E+08	1.75E+12	4.43E+12	6.79E+10
15	8.87E+12	3.30E+11	3.74E+11	1.10E+08	1.75E+12	4.43E+12	2.38E+11
16	1.33E+13	8.25E+11	2.83E+11	2.19E+08	3.79E+12	9.75E+12	3.39E+11
17	1.23E+13	8.66E+11	2.74E+11	2.19E+08	3.79E+12	9.75E+12	3.39E+11
18	2.91E+12	3.71E+11	1.55E+11	1.10E+08	2.04E+12	4.87E+12	6.79E+10
19	2.28E+12	2.47E+11	2.37E+11	1.10E+08	1.17E+12	3.10E+12	6.79E+10
20	6.33E+11	1.24E+11	1.28E+11	0.00E+00	7.29E+11	1.77E+12	0.00E+00
Total	**1.61E+14**	**1.31E+13**	**3.85E+12**	**3.50E+09**	**6.11E+13**	**1.54E+14**	**4.24E+12**

Table 5-24. Instream Direct Deposit Loading of Fecal Coliform (cfu/d) from Wildlife in the Spout Run Watershed.

Sub-watershed	Raccoon	Muskrat	Beaver	Geese-off season	Geese-in season	Wood Duck-off season	Wood Duck-in season
1	3.39E+06	7.50E+06	3.00E+04	3.20E+07	4.39E+07	7.29E+07	1.22E+08
2	2.94E+06	1.25E+06	3.00E+04	3.20E+07	4.39E+07	7.29E+07	1.09E+08
3	4.07E+06	4.00E+06	6.00E+04	4.00E+07	5.59E+07	9.72E+07	1.46E+08
4	7.01E+06	1.63E+06	9.00E+04	6.39E+07	9.19E+07	1.58E+08	2.43E+08
5	3.84E+06	1.25E+06	6.00E+04	3.60E+07	4.79E+07	8.51E+07	1.34E+08
6	1.58E+06	3.63E+06	3.00E+04	1.60E+07	2.40E+07	3.65E+07	6.08E+07
7	8.81E+06	1.75E+06	1.20E+05	7.99E+07	1.12E+08	1.94E+08	2.92E+08
8	1.13E+06	2.00E+06	3.00E+04	1.20E+07	1.60E+07	2.43E+07	3.65E+07
9	1.02E+07	2.00E+06	1.20E+05	9.59E+07	1.32E+08	2.31E+08	3.40E+08
10	5.42E+06	1.63E+06	6.00E+04	5.19E+07	7.19E+07	1.34E+08	1.94E+08
11	4.75E+06	1.25E+06	6.00E+04	4.79E+07	6.79E+07	1.09E+08	1.70E+08
12	6.78E+05	1.25E+06	0.00E+00	7.99E+06	1.20E+07	2.43E+07	2.43E+07
13	1.13E+06	1.13E+06	3.00E+04	1.20E+07	1.60E+07	2.43E+07	3.65E+07
14	1.81E+06	2.63E+06	3.00E+04	2.00E+07	2.80E+07	4.86E+07	7.29E+07
15	1.81E+06	5.13E+06	3.00E+04	2.00E+07	2.80E+07	4.86E+07	7.29E+07
16	4.52E+06	3.88E+06	6.00E+04	4.39E+07	5.99E+07	1.09E+08	1.58E+08
17	4.75E+06	3.75E+06	6.00E+04	4.39E+07	5.99E+07	1.09E+08	1.58E+08
18	2.03E+06	2.13E+06	3.00E+04	2.40E+07	3.20E+07	4.86E+07	8.51E+07
19	1.36E+06	3.25E+06	3.00E+04	1.20E+07	2.00E+07	3.65E+07	4.86E+07
20	6.78E+05	1.75E+06	0.00E+00	7.99E+06	1.20E+07	2.43E+07	2.43E+07
Total	**7.19E+07**	**5.28E+07**	**9.60E+05**	**6.99E+08**	**9.75E+08**	**1.69E+09**	**2.53E+09**

5.6. SUMMARY: CONTRIBUTION FROM ALL SOURCES

Based on the inventory of sources discussed in this chapter, a summary of the relative contribution of fecal coliform from each different source is given in Table 5-25. Over 98% of the fecal coliform load deposited in the watershed is from livestock. All other sources account for less than 1%. Direct stream inputs from cattle, wildlife, and straight pipes account for a small proportion (<0.1%) of the total fecal coliform load deposited in the watershed, and permitted point sources contribute an insignificant proportion of the total fecal coliform load (<0.01%). While these direct deposits contribute a small fraction of the overall fecal coliform load deposited in the watershed, their impact on water quality is much more direct and can be quite large. Fecal coliform deposited on the land

Interesting Fact:

One beef cow produces the same amount of fecal coliform each day as 23 people, 56 geese, 130 deer, 400 raccoons, 1800 muskrats, and 150,000 beaver.

surface may die before it is transported to the stream by precipitation events. The amount of land-deposited fecal coliform that makes its way into the stream depends on such factors as precipitation amount, intensity, and frequency; die-off rates; land cover; best management practices; and proximity to the stream. The LSPC model considers these and other factors when estimating fecal coliform loads to the receiving waters, as described in Chapter 7.

Table 5-25. Summary of Annual Fecal Coliform Loads in the Spout Run Watershed by Source.

Source		Annual Fecal Coliform Load (cfu/yr)	Percentage of Annual Load (%)
Direct Loading to Streams	Permitted Point Sources	1.38E+11	0.00%
	Straight pipes	3.99E+12	0.01%
	Cattle in Stream	1.53E+13	0.03%
	Wildlife in Stream	1.12E+12	0.00%
Loading to Land Surface	Failing Septic Systems	2.26E+13	0.04%
	Pets	3.01E+14	0.53%
	Biosolids	6.39E+13	0.11%
	Livestock	5.58E+16	98.58%
	Wildlife	3.96E+14	0.70%
Total		**5.62E+16**	**5.66E+16**

CHAPTER 6: SOURCE ASSESSMENT OF SEDIMENT

Sediment sources in the Spout Run watershed include both direct point sources, such as discharges from sewage treatment plants, and non-point sources, such as runoff from the land surface. Information on point sources and permitted non-point source discharges was obtained from VADEQ and VADCR. Sediment from the remaining non-point sources was modeled using the GWLF model (see Chapter 7). This model simulates runoff and sediment delivery from mixed land use watersheds. This section describes and quantifies the sediment loads from various point and non-point sources within the watershed.

6.1. PERMITTED SOURCES

Within the Spout Run watershed, there are two dischargers that hold individual Virginia Pollutant Discharge Elimination System (VPDES) permits. These include the Boyce Sewage Treatment Plant (STP) (VA0085171) and the Prospect Hill Springs Water Treatment Plant (WTP) (VA0090883), which are described in Section 5.1. The Boyce STP is permitted to discharge up to 0.05 million gallons per day (MGD) of treated sewage with an average TSS concentration of less than 30 mg/L and a maximum TSS concentration of less than 45 mg/L. Typical flows from this facility are considerably less than the permitted flow and have averaged 0.027 MGD since 2001. The Prospect Hill Springs WTP filters spring water as a drinking water source and discharges filter backwash water. This facility is permitted to discharge 0.0181 MGD of backwash water with an average TSS concentration of less than 30 mg/L and a maximum TSS concentration of less than 60 mg/L. The permitted sediment loads from these facilities are listed in Table 6-1.

In addition to permitted point sources, there are several permitted non-point sources within the Spout Run watershed. These include four construction stormwater general permits (Table 6-2). Sediment loads from these areas were estimated using the following equation from (Schueler, 1987). An estimated load of 4.61 tonnes/yr was calculated for these permits combined.

$$L = P * Rv * A * C * 0.0001134$$

Where,

L = Sediment load (tonnes/yr)

P = Average annual precipitation; 38.53 inches

Rv = 0.050+0.009 * percent impervious; 0.23

A = Disturbed area;

C = Average concentration in runoff; 100 mg/L

Table 6-1. Permitted Sediment Point Sources in the Spout Run Watershed.

Facility	Permit #	Permitted Flow (MGD)	Permitted TSS Conc. (mg/L)[a]	Wasteload Allocation	
				Annual WLA (tonnes/yr)	Daily WLA (tonnes/d)
Boyce STP	VA0085171	0.05	30/45	2.07	0.00852
Prospect Hill Springs WTP	VA0090883	0.0181	30/60	0.750	0.00411
			Total	2.82	0.0126

[a] When two numbers are given, the first is the average monthly limit and the second is the maximum or average weekly limit.

Table 6-2. Permitted Construction Stormwater General Permits in the Spout Run Watershed.

Facility Name	Permit No	Disturbed Area (acres)	Wasteload Allocation	
			Annual WLA (tonnes/yr)	Daily WLA (tonnes/d)
Boyce Crossing	VAR103538	18	1.81	0.00496
Meadow View	DCR01-06-101317	11.9	1.20	0.00328
Roseville Downs	DCR01-06-100414	10	1.00	0.00275
Blandy Experimental Farm	DCR01-08-100808	6	0.603	0.00165
	Total	45.9	4.61	0.0126

6.2. NON-POINT SOURCES

Non-point sources of sediment in the watershed include runoff from residential and urban areas, cropland, pasture, forest, transitional areas, and degraded riparian pasture. Erosion of the stream bank is another source of sediment in the watershed. Sediment loads from the non-point sources were modeled using the GWLF watershed model (see Chapter 7). Based on the calibrated model, sediment loads delivered to the watershed outlet from the various sources were calculated. The contributions from various sources within the watershed are shown in Figure 6-1. Based on GWLF modeling, the largest sediment source in the watershed is erosion of the stream banks, which delivers 60% of the sediment load. Degraded riparian pasture is the next

largest source, contributing 21% of the sediment load. Pastures contribute 12%, cropland contributes 3%, transitional lands contribute 2%, and the remaining land uses contribute 1% or less.
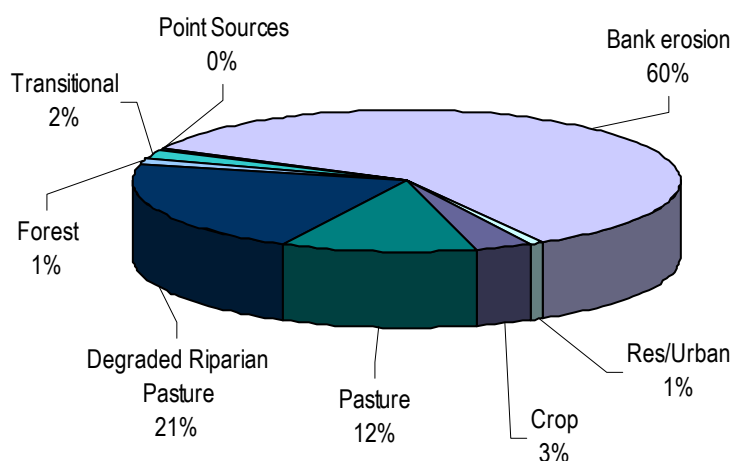
Figure 6-1. Sediment Loads from Various Sources in the Spout Run Watershed.

The contributions presented in Figure 6-1 represent the sediment loads delivered to the watershed outlet from various sources. These contributions are a function of the erosion rates on the various land uses and the amount of that land use present in the watershed. Figure 6-2 presents the unit area erosion rates for each land use. Erosion rates are by far highest in the degraded riparian pasture and the transitional areas. This is because limited vegetation is present in these areas. Erosion of cropland is the next highest, followed by pasture, residential areas, and forest. The stream bank erosion rates were not shown on this figure because of the difference in units, but stream bank erosion was estimated at 70 tonnes per year per linear mile of stream bank, or 43 kg/m/yr.
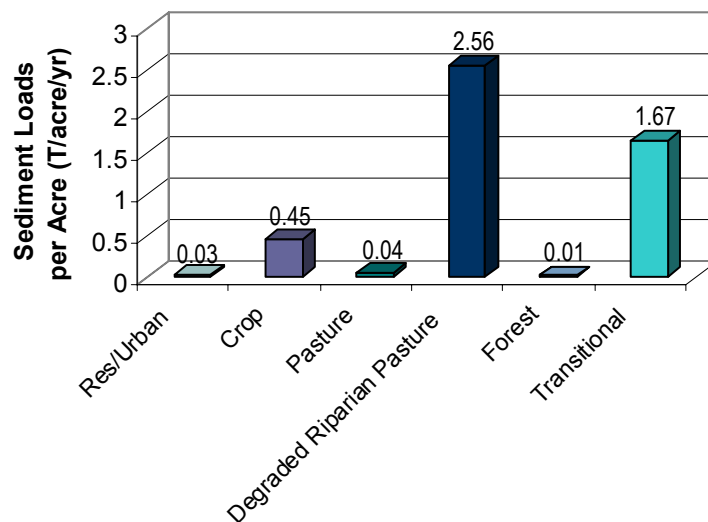
Figure 6-2. Sediment Loads per Acre from Sources within the Spout Run Watershed.

CHAPTER 7: MODELING APPROACH

An important step in developing a TMDL is establishing the relationship between pollutant loadings (both point and nonpoint) and instream water quality conditions. This relationship must be representative of the watershed and stream being assessed and must be predictive of future water quality conditions given established source loads. Once this relationship is developed, management options for reducing pollutant loadings to the stream can be evaluated. The best way to establish this predictive linkage between loads and instream water quality is to develop a computer simulation model of the watershed. The watershed model considers the following key processes in establishing this linkage: the spatial and temporal distribution of source loads in the watershed, local climate and precipitation patterns, pollutant accumulation on the land surface, washoff and runoff processes, stream hydrology, and the fate and transport of pollutants. This chapter describes the modeling approach used in the development of the Spout Run bacteria and sediment TMDLs. A watershed model is a useful tool for evaluating various management options and scenarios, but should be used in concert with an instream monitoring program and adaptive management approach to successfully achieve targeted water quality goals (see Chapter 9).

7.1. MODEL DESCRIPTION

The Loading Simulation Program C++ (LSPC) watershed model was used to simulate hydrology and bacteria in Spout Run. LSPC is a public domain watershed model developed by Tetra Tech, Inc. (Tetra Tech, 2005) and maintained as part of USEPA's TMDL Modeling Toolbox. LSPC is a dynamic watershed model that is used to simulate hydrologic processes, sediment, pollutant accumulation, transport, and general water quality. LSPC was developed by streamlining algorithms used in the Hydrological Simulation Program Fortran (HSPF) model (Duda *et al.*, 2001) and rewriting those algorithms in a Microsoft Visual C++ programming architecture. The LSPC model simulates point source and nonpoint source pollutant loadings, performs flow routing through streams, and simulates instream water quality processes. LSPC simulates the runoff of water and accumulated pollutants from both pervious and impervious portions of the

watershed. LSPC simulates pollutant accumulation, die-off, and washoff according to the distribution of land uses, soils, and geographic features. LSPC then simulates the routing of water and pollutants through the stream channel network, considering instream processes such as die-off.

Fecal coliform bacteria was simulated as a dissolved pollutant using the general constituent pollutant model (GQUAL) in LSPC. Simulated fecal coliform concentrations were then translated to *E. coli* concentrations using VADEQ's translator equation (VADEQ, 2003).

Sediment in the Spout Run watershed was modeled using the BasinSim software (Dai *et al.*, 2000). BasinSim is a windows-based version of the Generalized Watershed Loading Function (GWLF) model developed by Haith *et al.* (1992). GWLF is a loading function model that simulated runoff and sediment delivery using simple, yet widely acceptable, algorithms. Runoff is calculated using the Soil Conservation Service curve number equation, and erosion is simulated using the Universal Soil Loss Equation (USDA, 2003)

7.2. INPUT DATA REQUIREMENTS

The LSPC model requires a wide variety of input data to describe hydrology, pollutant sources, and land use characteristics within the watershed. The different types and sources of input data used to develop the TMDL for the Spout Run watershed are discussed below. The ArcGIS 9 geographical information system program was used to display and analyze watershed information for input into LSPC. Microsoft Access was used to store and manage model input parameters and data. Microsoft Excel was used to summarize and display model output.

7.2.1. Meteorological Data

Hourly precipitation and evapotranspiration data are needed for the LSPC watershed model to simulate flow and bacteria concentrations. Precipitation data for weather stations near the Spout Run watershed were obtained from the National Climatic Data Center (NCDC, 2009). Daily maximum and minimum temperatures were also obtained from NCDC, and used to calculate hourly evapotranspiration. For the Spout Run TMDL, data were obtained from a total of four weather stations ranging from 4 to 17 miles from the Spout Run watershed (Figure 7-1 and Table

7-1). Using data reported from these stations, an hourly precipitation and evapotranspiration data set for the Spout Run watershed was developed for the time period of 1/1/1991 through 12/31/2008.

The Winchester 7SE Weather Station (449186) was used as the primary station for generating Spout Run TMDL weather files. The Winchester 7SE station is less than 4 miles outside of the Spout Run watershed, and it represented the closest station with daily precipitation and temperature data. As with most weather stations, there were occasional gaps in data at the Winchester 7SE station from either station inactivity or equipment malfunction. These data gaps had to be patched with reliable data from other surrounding stations. Gaps in daily precipitation and temperature data were patched with data from other stations in the following order of priority: Winchester (449181) then Mt. Weather (445851). If data from the first priority patching station was unavailable then the next priority station was consulted. Overall, only 3.9% of precipitation data, 3.8% of minimum temperature data, and 3.7% of maximum temperature data were patched due to data gaps at the Winchester 7SE station (Table 7-2). These data gaps were primarily filled with data from the Winchester station (3.0% of precipitation data, 2.9% of minimum temperature data, and 2.8% of maximum temperature data). Less than 1% of data was missing from both the Winchester 7SE and Winchester stations and was filled with data from the Mt. Weather station.
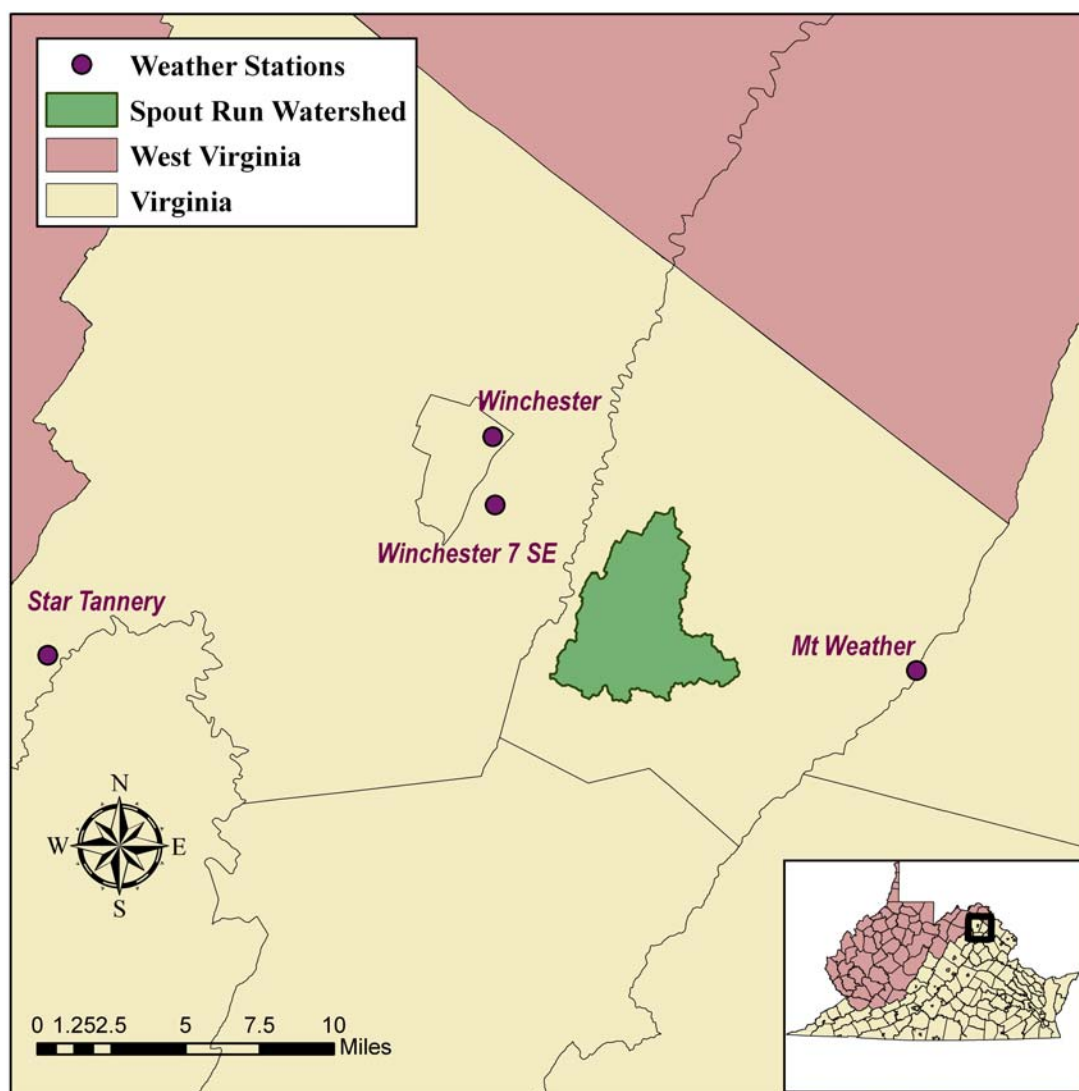
Figure 7-1. Weather Stations Used in Spout Run TMDL Development.

Table 7-1. Meteorological Datasets Compiled for the Spout Run LSPC Model.

Station Name	Station ID	Data Frequency	Data Type	Period of Record	Elevation (ft)	Distance From Watershed (mi)
Winchester 7 SE	449186	Daily	Min Temp.	1979-2009	680	3.99
			Max Temp.			
			Max Temp.			
Winchester	449181	Daily	Precipitation	1982-2009	720	5.43
			Min Temp.			
			Max Temp.			
Mt. Weather	445851	Daily	Precipitation	1948-2009	1720	5.96
			Min Temp.			
			Max Temp.			
Star Tannery	448046	Hourly	Precipitation	1948-2009	950	16.93

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Table 7-2. Spout Run TMDL Weather File Patching Summary.

Source	Hourly Precipitation		Daily Min. Temp.		Daily Max. Temp.	
	# of Data Points	% of Record	# of Data Points	% of Record	# of Data Points	% of Record
Winchester 7SE	6317	96.1%	6328	96.2%	6332	96.3%
Winchester	197	3.0%	186	2.8%	182	2.8%
Mt. Weather	61	0.9%	61	0.9%	61	0.9%
Total Patched	258	3.9%	247	3.8%	243	3.7%
Total Data Set	6575	100.0%	6575	100.0%	6575	100.0%

After a complete daily precipitation data set was obtained, the daily precipitation values were disaggregated using the hourly precipitation patterns observed at the Star Tannery station (16.93 miles outside of the watershed), the closest station with hourly precipitation data. This disaggregation of daily rainfall to hourly rainfall was performed using the WDMUtil program available as part of USEPA's BASINS software.

Maximum and minimum daily temperature data sets were then used to develop an hourly potential evapotranspiration data set. Potential evapotranspiration was computed by the Hamon method (Hamon, 1961) from station latitude and daily minimum and maximum temperatures. This computation was conducted using the WDMUtil program available as part of USEPA's BASINS software.

7.2.2. Land Use

Section 3.7 describes the land cover within the Spout Run watershed. Land cover data for the watershed was obtained from the 2005 Virginia Department of Forestry's (VADOF) Virginia Land Use Dataset (VADOF, 2005), which is currently the most up-to-date land cover data available for the Spout Run watershed. This land cover dataset was also supplemented by the 2001 National Land Cover Dataset (USGS, 2001). To facilitate modeling, some of the land cover categories in the VADOF data set were aggregated and some were disaggregated to produce TMDL land use classifications that have distinctive bacteria and sediment loadings. Table 7-3 describes how land use classifications used in the Spout Run TMDL were derived from the VADOF data set and other sources.

Table 7-3. Source of Land Use Classifications Used in the Spout Run TMDL.

VADOF Land Cover Classifications	TMDL Land Use Classifications	Derived From
Water	Water	Combination of VADOF Water and NLCD Water
Pavement	Impervious Urban/Transportation	Sum of VADOF Pavement and Rooftop
Rooftop		
Residential/Industrial	Residential	VADOF Residential/Industrial and structures data
Quarries/Mines	Transitional	Sum of VADOF Quarries/Mines, Natural Barren, Bare Soil, Forest Harvest, and DCR construction permits
Natural Barren		
Bare Soil		
Forest Harvest		
Hardwood Forest	Forest	Sum of VADOF Hardwood Forest, Pine Forest, and Mixed Forest
Pine Forest		
Mixed Forest		
Crop/Pasture/Hay	Pasture/Hay	VADOF Crop/Pasture/Hay minus TMDL Degraded Riparian Pasture and TMDL Cropland
	Degraded Riparian Pasture	100 m buffer around streams with visible erosion and cattle access as determined from aerial imagery
	Cropland	VADOF Crop/Pasture/Hay times percentage of NLCD Row Crops to total of NLCD Row Crops and Pasture/Hay
Salt Marsh	N/A	

For those land uses that were aggregated from VADOF classifications, the acreages of the component categories were simply summed to obtain the aggregated acreage. For the crop/pasture/hay land cover classification, additional information was needed to disaggregate this category into separate land uses that vary in bacteria and sediment loading potential. This category was divided into the following categories: degraded riparian pasture, cropland, and pasture/hay.

Degraded riparian pasture is a land use classification that was developed by the Chesapeake Bay Program in an effort to more accurately represent areas of active bank erosion. This classification represents areas with no riparian vegetation and where cattle have unlimited access to the stream. These areas are locations of high bank erosion rates, because cattle hooves trample and dislodge bank sediments and because the bank soil is not stabilized by riparian vegetation. These areas were identified in the Spout Run watershed from aerial imagery, and designated as a 100-meter band along either side of a visually eroding stream bank with limited

vegetation and cattle access. Figure 7-2 shows the areas within the watershed that were designated as degraded riparian pasture, and Figure 7-3 shows an example of aerial imagery used to designate such areas.
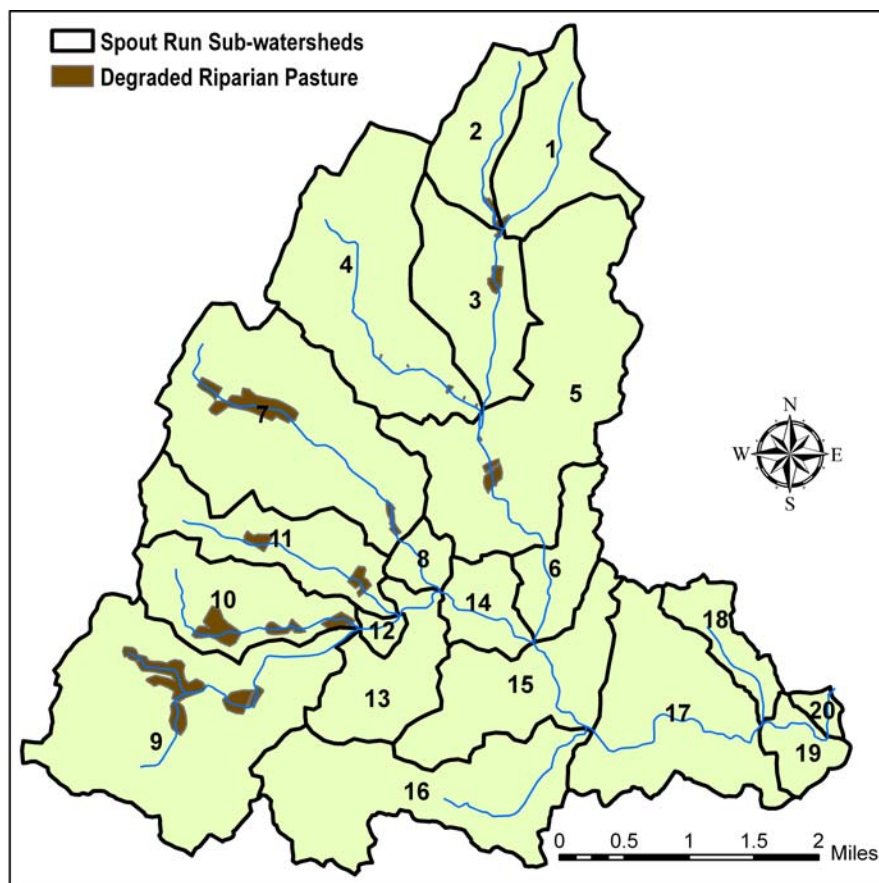
Figure 7-2. Degraded Riparian Pasture Areas in the Spout Run Watershed.

Cropland was disaggregated from the VADOF crop/pasture/hay category using additional information from the 2001 National Land Cover Dataset (NLCD) for Virginia (USGS, 2001). Like the VADOF data set, the NLCD data set was developed from satellite imagery, however, the NLCD data were captured in the early 2000s, so it is not as current as the VADOF data set. This land cover data set, however, classified cropland and pasture/hay land separately. To determine the portion of the VADOF crop/pasture/hay category that is cropland, the percentage

of NLCD cropland to NLCD total crop/pasture/hay in each sub-watershed was applied to the VADOF crop/pasture/hay category. This method assumes that while the acreages of crop and pasture land may have changed from 2001 to 2005, the percentage of cropland to pasture land has remained constant. After this calculation was made, the acreage of pasture/hay disaggregated from the VADOF data set could be calculated as the crop/pasture/hay acreage minus the derived degraded riparian pasture acreage minus the derived cropland acreage.
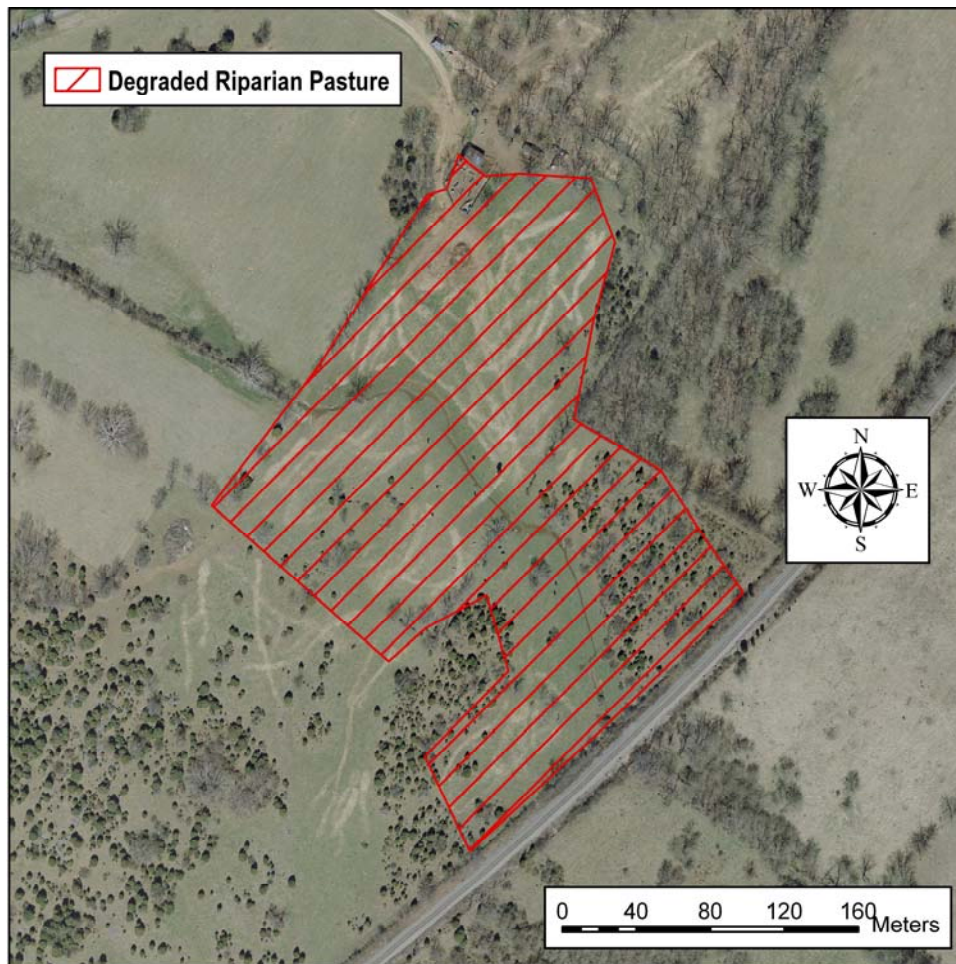
Figure 7-3. Example of Areas Designated as Degraded Riparian Pasture.

After necessary aggregation and disaggregation of the VADOF land cover data set was conducted, the land use was then verified against other data sources. First, certain land use

categories, such as water and cropland, were verified against aerial imagery. The Clarke County structures database was then used to verify residential land uses. Within each sub-watershed, the residential acreage was then checked to make sure that it represented at least an average of 0.25 acre lot sizes for the homes within that sub-watershed. Lastly, information from DCR construction stormwater permits was used to verify transitional land uses. The number of acres reported as disturbed in construction stormwater permits was added to the transitional land use category in the respective sub-watersheds. After these verifications and modifications, a robust land use data set was obtained for the Spout Run watershed. Table 7-4 shows the land use breakdown in each sub-watershed. These land use values were used to represent the watershed in the LSPC and GWLF models, and they were used to calculate land use specific bacteria and sediment loadings for the watershed. The water land use and the impervious urban/transportation land use were modeled as impervious land segments, and all other land uses were modeled as pervious land segments.

Table 7-4. Land Use in the Spout Run Watershed (acres).

Sub-watershed	Water	Impervious Urban/Transportation	Resi-dential	Trans-itional	Forest	Pasture/ Hay	Crop	Degraded Riparian Pasture	Total
1	1	15	13	0	260	227	34	2	552
2	0	0	1	0	200	178	20	5	405
3	0	14	38	0	290	298	1	12	653
4	0	11	14	0	391	839	54	1	1311
5	1	52	167	18	318	1003	37	15	1611
6	2	5	24	0	76	227	8	0	342
7	5	35	91	22	161	1113	14	66	1507
8	1	0	7	0	72	46	0	0	127
9	0	29	127	1	198	1257	17	94	1723
10	0	39	67	0	104	337	2	58	609
11	0	29	54	0	134	376	5	24	622
12	0	0	0	0	33	24	0	0	57
13	0	16	13	0	124	348	1	0	502
14	3	3	17	0	73	166	0	0	263
15	0	22	52	6	285	378	9	0	753
16	3	30	55	1	303	690	51	0	1134
17	5	20	24	0	285	714	2	0	1048
18	0	0	2	0	31	210	0	0	243
19	1	2	2	0	176	11	0	0	192
20	1	3	3	3	23	23	0	0	56
Total	**25**	**326**	**773**	**51**	**3537**	**8466**	**255**	**278**	**13711**
%	**0.18%**	**2.38%**	**5.63%**	**0.37%**	**25.80%**	**61.75%**	**1.86%**	**2.02%**	**100.00%**

7.2.3. Hydrologic Model Parameters

The LSPC model was constructed to simulate hydrology and bacteria in Spout Run. Because the hydrology of the watershed is so important in controlling the loading and concentrations of pollutants in the stream, the model was first constructed and calibrated to accurately predict the flow of Spout Run as observed at the USGS flow gaging station. Once the model was accurately representing the hydrology of the watershed, then the bacteria loadings were included in the model and the water quality was calibrated to match observed bacteria data collected from the stream.

A number of different model parameters are required in the LSPC model to simulate hydrology. Table 7-5 shows the different hydrologic parameters used in the Spout Run LSPC model. This table describes how the value for each parameter was obtained and the variables by which the parameter was altered. Some of the parameters were constants used throughout the model. Parameters that depend on seasonal cycles were varied by month. Other parameters were given a separate value for each sub-watershed, land use, or soil type. Sub-watersheds used in the model are shown in Figure 3-4. Land uses considered in the model were the eight land use categories tabulated in Table 7-4. Soil types considered in the model were those hydrologic soil types identified in Section 3.4 for each of the different sub-watersheds.

The source of parameter values used in the model varied depending upon the parameter. Some of the parameters, such as physical characteristics of the stream channel, were specifically measured in the field by VADEQ staff. Other parameters were obtained by analyzing GIS coverages of the watershed. For instance, the slopes of each reach were obtained by combining digital elevation data for the watershed and stream coverages. Other parameters were estimated from literature values, and some parameters were initially estimated and then used as calibration parameters. These calibration parameters were adjusted during the calibration process to optimize the agreement between simulated flows and measured flows. The resulting values for hydrologic parameters in the calibrated Spout Run LSPC model are listed in APPENDIX A.

Table 7-5. Hydrologic Model Parameters for the Spout Run LSPC Model.

Parameter	Parameter Description	Varied By	Source
DEPINIT_M	Initial water depth	Sub-watershed	Field measurement
LEN_M	Longitudinal length of the reach	Sub-watershed	GIS measurement
SLOPE	Longitudinal slope of the reach	Sub-watershed	GIS measurement
WID_M	Cross-sectional bankfull width	Sub-watershed	Field measurement
DEP_M	Cross-sectional bankfull depth	Sub-watershed	Field measurement
R1	Ratio of bottom width to bankfull width	Sub-watershed	Field measurement
R2	Upper bank slope	Sub-watershed	Field measurement
W1	Ratio of bank width to bankfull width	Sub-watershed	Field measurement
MANNING_N	Manning's roughness coefficient	Sub-watershed	Estimated from literature
CRRAT	Ratio of maximum velocity to mean velocity	Sub-watershed	Estimated from literature
SLSUR	Slope of overland flow	Sub-watershed and Land use	GIS measurement
LSUR	Length of overland flow	Sub-watershed and Land use	GIS measurement
MELEV	Mean watershed elevation	Sub-watershed	GIS measurement
RMELEV	Mean reach elevation	Sub-watershed	GIS measurement
LZSN	Lower zone nominal soil moisture storage	Soil type and Land use	Calibrated
INFILT	Index to infiltration capacity	Soil type and Land use	Calibrated
KVARY	Variable groundwater recession	Constant	Calibrated
AGWRC	Base groundwater recession	Constant	Calibrated
PETMAX	Temperature below which evapotranspiration is reduced	Constant	Estimated from literature
PETMIN	Temperature below which evapotranspiration is set to zero	Constant	Estimated from literature
INFEXP	Exponent in infiltration equation	Constant	Estimated from literature
INFILD	Ratio of max/mean infiltration capacities	Constant	Estimated from literature
DEEPFR	Fraction of groundwater inflow to deep recharge	Constant	Calibrated
BASETP	Fraction of remaining evapotranspiration from baseflow	Constant	Calibrated
AGWETP	Fraction of remaining evapotranspiration from active groundwater	Constant	Calibrated
CEPSC	Interception storage capacity	Land use and month	Calibrated
UZSN	Upper zone nominal soil moisture storage	Land use and month	Calibrated
NSUR	Manning's n for overland flow	Constant	Calibrated
INTWF	Interflow inflow parameter	Constant	Calibrated
IRC	Interflow recession parameter	Constant	Calibrated
LZETP	Lower zone evapotranspiration parameter	Land use and month	Calibrated

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7.2.4. Bacteria Model Parameters

Following successful calibration of Spout Run hydrology, the LSPC model was expanded to simulate fecal coliform concentrations. A number of different model parameters are required in the LSPC model to simulate fecal coliform. Table 7-6 shows the different water quality parameters used in the Spout Run LSPC model to simulate fecal coliform. The monthly accumulation rate (ACQOPM) and maximum storage (SQOLIM) were calculated from bacteria source information for each sub-watershed and land use on a monthly basis. All other water quality parameters were constants that were estimated from literature values and adjusted (if necessary) during the calibration process to optimize the agreement between simulated fecal coliform levels and measured concentrations. The resulting values for water quality parameters in the calibrated Spout Run LSPC model are listed in Table 7-6 and APPENDIX B.

Table 7-6. Bacteria Model Parameters for the Spout Run LSPC Model.

Parameter	Parameter Description	Varied By	Source	Calibrated Value
WSQOP	Rate of surface runoff which will remove 90% of stored pollutant	Constant	Calibrated	0.18
IOQC	Concentration of pollutant in interflow	Constant	Estimated from spring data	0
AOQC	Concentration of pollutant in active groundwater	Constant	Estimated from spring data	0
ACQOPM (MON-ACCUM)	Monthly parameter for rate of accumulation of pollutant	Sub-watershed, land use, and month	Calculated from source inventory	See APPENDIX B
SQOLIM	Monthly parameter for maximum storage of pollutant	Sub-watershed, land use, and month	Literature derived fraction of accumulation rate	See APPENDIX B
FSTDEC	First order decay rate for pollutant	Constant	Calibrated	0.85
THFST	Temperature correction coefficient for first order decay of pollutant	Constant	Calibrated	1.07

7.2.5. GWLF Model Parameters

The GWLF model requires three input files: a weather input file, a transport input file, and a nutrient input file. Since nutrients were not being simulated in this project, a blank nutrient input file was used. Weather data for the GWLF model was obtained from the weather files developed for the LSPC model (see Section 7.2.1). Parameters for the transport file were developed using watershed information from the GIS system, guidance from the GWLF user's manual (Haith *et al.*, 1992), USDA Revised Universal Soil Loss Equation software (USDA, 2003), and best professional judgment. Final calibrated GWLF model parameters are listed in Table 7-7 through Table 7-9. The modeling period for the Spout Run GWLF model was 4/1/2002 – 3/31/2008. This included a 1 year model spin-up period to eliminate the influences of initial model conditions. Results were reported for the 5 year period from 4/1/2003 – 3/31/2008.

Table 7-7. General Transport Parameters for the Spout Run GWLF Model.

Parameter	Value	Source
Recession coefficient	0.0083	Calibrated
Seepage coefficient	0.001	Calibrated
Initial unsaturated storage	10	Irrelevant based on 1 yr model spin-up
Initial saturated storage	0	
Initial snow	0	
Sediment delivery ratio	0.072	Calibrated
Unsaturated available water capacity	10	GWLF manual guidance

Table 7-8. Monthly Parameters for the Spout Run GWLF Model.

Month	ET Coefficient	Daylight Hours	Growing Season	Erosion Coefficient
Apr	0.99	13	1	0.3
May	0.99	14	1	0.3
Jun	0.99	14.5	1	0.3
Jul	0.99	14.3	1	0.3
Aug	0.99	13.4	1	0.3
Sep	0.99	12.2	1	0.3
Oct	0.75	11	1	0.1
Nov	0.75	10	1	0.1
Dec	0.75	9.4	1	0.1
Jan	0.75	9.7	1	0.1
Feb	0.99	10.6	1	0.1
March	0.99	11.8	1	0.1

Table 7-9. Land Use Parameters for the Spout Run GWLF Model.

Land Use	Area (Ha)	Curve Number	KLSCP
Residential (pervious)	297	74	0.00026
Cropland	103	82	0.0035
Pasture	3426	79	0.00035
Degraded Riparian Pasture	112	86	0.02
Forest	1432	70	0.000085
Transitional (pervious)	18.7	91	0.013
Impervious	132	98	0.15
Open Water	9.99	100	0
Residential (impervious)	15.6	92	0.15
Transitional (impervious)	2.07	89	0.15

7.3. ACCOUNTING FOR BACTERIA SOURCES

7.3.1. Modeling Permitted Point Sources

There are two permitted dischargers in the Spout Run watershed (see Section 5.1). Of these, only one (the Boyce Sewage Treatment Plant) is permitted to discharge *E. coli*. During TMDL allocation model runs, this discharger was modeled using the maximum permitted design flow of 0.05 MGD and maximum permitted *E. coli* concentration of 126 cfu/100ml. During calibration and existing condition model runs, permitted point sources were modeled using more representative flows and bacteria concentrations.   Flows and bacteria concentrations were modeled based on monthly data reported to VADEQ on Discharge Monitoring Reports (DMRs). Boyce STP flows averaged 0.027 MGD from 2000 – 2008. Fecal coliform concentrations from 2000 – 2005 averaged 99.5 cfu/100ml, and *E. coli* concentrations from 2005 – 2008 averaged 4.9 cfu/100ml.

7.3.2. Modeling Direct Deposits

Fecal coliform loading from straight pipes was modeled as directly entering the stream with no die-off from source to stream. The daily fecal coliform loadings from straight pipes calculated in Table 5-5 were modeled as direct inputs within the respective sub-watersheds.

A portion of fecal coliform loadings from animals that live or wade in the stream was also modeled as a direct input. This includes loadings from cattle, raccoon, muskrat, beaver, geese, and ducks. For cattle, direct deposit loadings were determined from the number of cattle with

stream access, the total loading from those cattle, the percentage of time spent in the stream, the available tree cover around perennial stream access areas, and cloud cover, as described in Section 5.4.1. The calculated direct deposit loading from cattle by sub-watershed and month was presented in Table 5-17. These loads were modeled as continuous direct inputs varying daily within the respective sub-watersheds.

Direct deposit loadings from wildlife species were determined based on the total loading from those species and the percent of load deposited directly in the stream (see Section 5.5). The calculated direct deposit loading from wildlife by sub-watershed and season was presented in Table 5-24. These loads were modeled as continuous direct inputs varying monthly within the respective sub-watersheds.

7.3.3. Modeling Land Applied Sources

Fecal coliform loads from failing septic systems, pets, and biosolids were modeled as land applied loads. Fecal coliform loads from livestock and wildlife that were not deposited directly in the stream were also modeled as land applied loads. Chapter 5 describes and quantifies the load from each source deposited onto the land surface in each sub-watershed. For modeling purposes, the land applied loads from each source within a sub-watershed were distributed among the land uses occupied by that source. With the exception of biosolids, loads were distributed evenly across the total acreage of land occupied by a source within the sub-watershed. Biosolids permit information was used to more precisely pinpoint individual fields and loadings. Table 7-10 shows the land uses across which fecal coliform loads were distributed for each source. In the LSPC model, these loads were represented by a daily loading rate for each sub-watershed and land use combination. The daily loading rate was calculated as the total daily load from all sources to a particular land use in a particular sub-watershed divided by the area of that land use in the sub-watershed. Because loadings and some animal numbers varied by month, the daily loading rates also were varied by month. The daily loading rates were expressed in the LSPC model in the form of an Accumulation Table (ACCUM_TABLE). The Accumulation Table for the calibrated existing condition is presented in APPENDIX B.

Once fecal coliform is deposited on the land surface, precipitation and runoff is needed to transport the bacteria to surface waters. The LSPC model simulates precipitation events based

on the weather data inputs, and simulates runoff from a variety of land use and hydrologic parameters (see Section 7.2.3).

Table 7-10. Summary of Land Uses Receiving Fecal Coliform Loads From Various Sources.

Source	Impervious Urban/ Transportation	Residential	Transitional	Forest	Pasture/Hay	Cropland	Degraded Riparian Pasture
Failing Septic Systems		x					
Pets		x					
Biosolids					x	x	
Livestock					x		x
Dairy					x	x	
Deer	x	x	x	X	x	x	x
Raccoon	x	x	x	X	x	x	x
Muskrat				X		x	
Beaver				X	x		x
Geese	x	x	x	X	x	x	x
Duck	x	x	x	X	x	x	x
Wild Turkey			x	X	x	x	x

7.3.4. Modeling Fecal Coliform Die-off

The die-off of fecal coliform on the land surface and in the stream was modeled according to the following first order decay function:

$$C_t = C_0 10^{-Kt}$$ [7-1]

where: C_t = concentration or load at time t,

C_0 = starting concentration or load,

K = decay rate (day^{-1}),

and t = time in days.

Following successful water quality calibration, a resulting decay rate of 0.85 day^{-1} was used for fecal coliform die-off in the stream. On the land surface, fecal coliform die-off was estimated as 0.51 day^{-1} during warm months and 0.36 day^{-1} during cold months (USEPA, 2000). This decay rate was represented in LSPC by specifying a maximum surface buildup of 1.5 times the daily

buildup rate during April through September and 1.8 times the daily buildup rate during October through March.

7.3.5. *E. coli* Translator Equation

Output from the LSPC model was generated as an hourly timeseries and daily average time series of fecal coliform concentrations. *E. coli* concentrations were determined using the following translator equation:

$$\log_2 EC(cfu/100mL) = -0.0172 + 0.91905 * \log_2 FC(cfu/100mL) \qquad \text{[7-2]}$$

This translator was implemented as a post-processing step in a spreadsheet after running the model.

Water quality calibration of the model was conducted using fecal coliform, since source information and observed monitoring data were in the form of fecal coliform measurements. For TMDL scenarios, however, fecal coliform concentrations were translated to *E. coli*. This allowed direct comparison of TMDL loadings to the *E. coli* water quality standards.

The TMDL was set to meet the monthly geometric mean *E. coli* standard of 126 cfu/100ml and meet the instantaneous *E. coli* target of 235 cfu/100ml at a violation rate less than 10.5%. Instantaneous *E. coli* concentrations were translated from the daily average of hourly fecal coliform concentrations simulated for each day. Monthly geometric means were calculated by taking the geometric mean of translated daily average fecal coliform concentrations within each calendar month.

7.4. ACCOUNTING FOR SEDIMENT SOURCES

There are two permitted point source discharges in the Spout Run watershed (Section 6.1). During TMDL allocation model runs, permitted point sources were modeled using maximum permitted design flows and permitted monthly average TSS concentrations (see Table 6-1). During calibration and existing condition model runs, permitted point sources were modeled using flows more representative than design flows. Flows and TSS concentrations for each facility were based on flows reported by the facility on discharge monitoring reports (DMRs).

Sediment from stream bank erosion within Spout Run and its tributaries was accounted for using the empirical estimation model developed by Evan *et al.* (2003). This empirical model estimates the lateral erosion rate (LER) according to the equation below:

$$LER = aQ^{0.6}$$

where,

LER = lateral erosion rate (m/month)

a = erosion coefficient

Q = stream flow (m^3/s).

The erosion coefficient in this equation was estimated from the empirical relationship below:

$$a = (0.00147*PD)+(0.000143*AD)-(0.000001*CN)+(0.000425*KF)+$$
$$(0.000001*MS)-0.000016$$

where,

a = erosion coefficient

PD = percent developed land in watershed

AD = animal density measured in animal units/acre

CN = area-weighted curve number value

KF = area-weighted k factor

MS = mean topographic slope (%).

7.5. ACCOUNTING FOR BEST MANAGEMENT PRACTICES (BMPS)

The Virginia Department of Conservation and Recreation tracks all agricultural best management practices (BMPs) that are cost-shared in Virginia. Based on this database, eleven agricultural BMPs have been installed in the Spout Run watershed using cost-shared assistance. It is possible that some BMPs have been installed voluntarily without financial assistance, but lacking any information on those practices, the TMDL was developed to consider only those BMPs tracked by DCR or readily observable from aerial imagery (such as stream exclusion practices).

Agricultural best management practices installed in the Spout Run watershed are shown in Figure 7-4 and listed in Table 7-11. These BMPs were incorporated into land use classifications and livestock access information used in TMDL development. For instance, livestock access information and land use information were modified to account for locations where stream exclusion fencing has been installed.
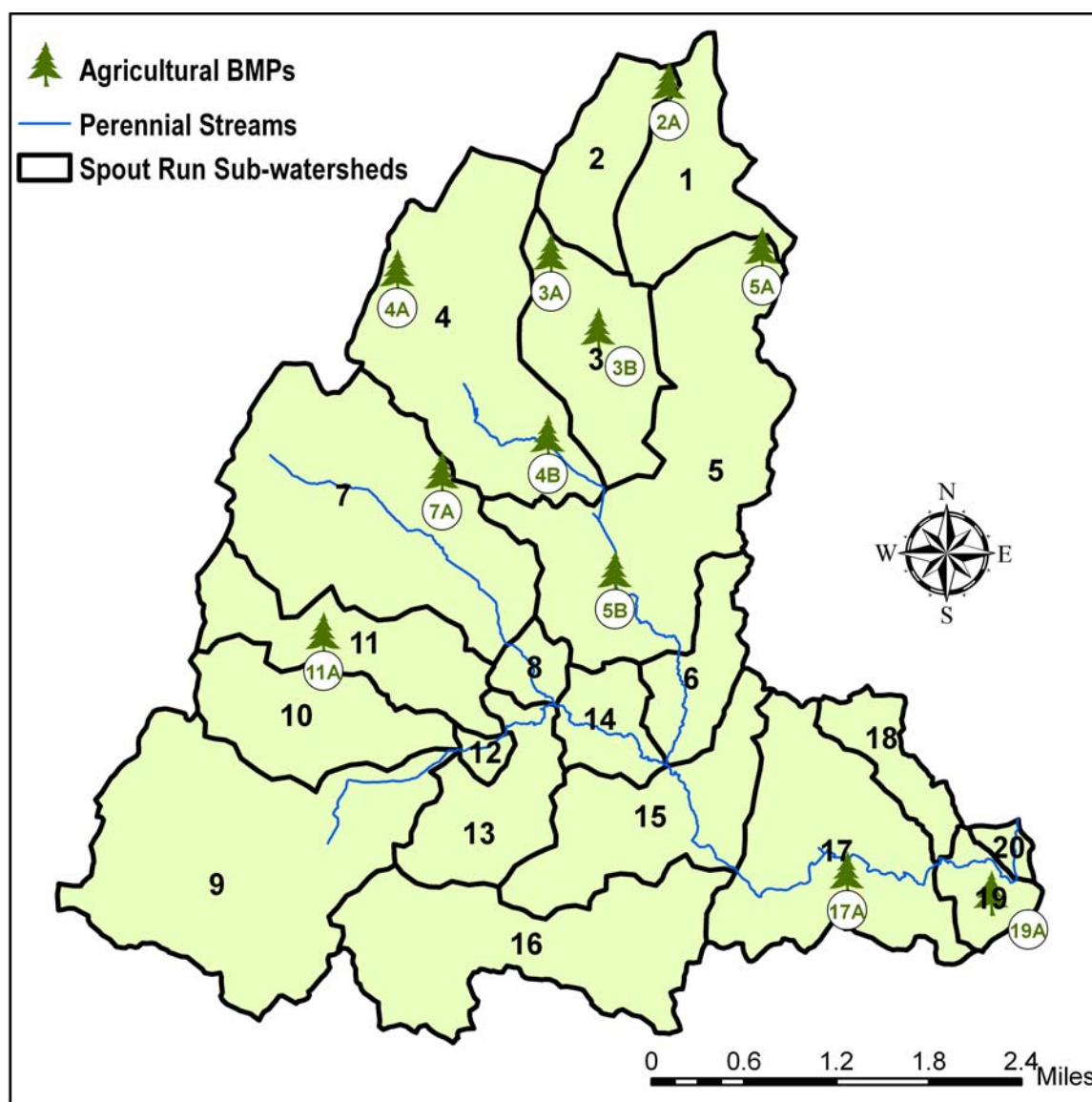
Figure 7-4. Agricultural Best Management Practices Installed in the Spout Run Watershed.

Table 7-11. Agricultural Best Management Practices Installed in the Spout Run Watershed.

Map ID	Sub-watershed	Practice	Practice Description	Extent	Year Installed
2A	2	SL-1	Permanent vegetative cover on cropland	24 acres	2001
3A	3	SL-1	Permanent vegetative cover on cropland	42 acres	2001
3B	3	SL-6	Grazing land protection	200 linear feet	2002
4A	4	SL-6	Grazing land protection	1100 linear feet	2001
4B	4	WP-2	Stream protection	200 linear feet	2001
5A	5	SL-6	Grazing land protection	800 linear feet	2000
5B	5	WP-2	Stream protection	24.1 square feet	1995
7A	7	WP-3	Sod waterway	59 linear feet	1991
11A	11	SL-1	Permanent vegetative cover on cropland	22 acres	2008
17A	17	SL-6	Grazing land protection	1400 linear feet	1999
19A	19	SL-6	Grazing land protection	1200 linear feet	2006

7.6. ACCOUNTING FOR TRENDS IN LIVESTOCK POPULATIONS

Livestock population estimates presented in Section 5.4 were obtained from 2007 or 2008 agricultural statistics for Clarke County. During calibration of the water quality model, it was apparent that bacteria loads to Spout Run were higher in the 1990s than in 2008. To account for this difference agricultural census data from 1992 through 2007 were consulted. Livestock direct deposit loads were adjusted based on changing animal numbers during this time period. Table 7-12 shows the change in county and watershed cattle numbers during the modeling period.

Table 7-12. Changes in Livestock Estimates During the Modeling Period.

Year	Cattle Population	
	Clarke Co.	Spout Run Watershed
1992	18847	3061
1997	17277	2803
2002	16887	2741
2007	14905	1341

7.7. MODEL CALIBRATION

Model calibration is the process of selecting model parameters that provide an accurate representation of the watershed. In this section, the procedures followed for calibrating the hydrology, water quality, and sediment components of the LSPC and GWLF models are discussed.

7.7.1. Hydrologic Calibration

The USGS flow gage on Spout Run has only been in operation since August 2002, so a hydrology calibration period of 2003-2008 was selected for the Spout Run LSPC model. This time period represented both higher flow and lower flow periods. The Spout Run LSPC model was run for this time period and then the calibration parameters identified

Definition:

Calibration – Calibration is the process of adjusting model parameters until the computer model produces the best possible fit with real-world data.

in Table 7-5 were adjusted until simulated stream flow matched observed stream flow during that time period. A reasonable match or fit between the simulated and observed flow was determined according to the hydrology calibration criteria shown in Table 7-13. These criteria are consistent with the criteria recommended in the HSPF Expert System (HSPEXP) developed by the USGS (Lumb *et al.*, 1994) to assist in hydrologic calibration. Final calibrated values for all hydrologic parameters are shown in APPENDIX A.

Table 7-13. Hydrology Calibration Criteria Used for the Spout Run LSPC Model.

Errors (Simulated-Observed)	Calibration Criteria
Error in total volume:	10%
Error in 50% lowest flows:	10%
Error in 10% highest flows:	15%
Seasonal volume error - Summer:	30%
Seasonal volume error - Fall:	30%
Seasonal volume error - Winter:	30%
Seasonal volume error - Spring:	30%
Error in storm volumes:	20%
Error in summer storm volumes:	50%

A successful hydrologic calibration was obtained for the Spout Run LSPC model. Simulated flow during the calibration period (2003-2008) correlated nicely with observed flow during that time period. The error statistics for the successful hydrologic calibration are shown in Table 7-14. Figure 7-5 compares the simulated and observed flows in Spout Run during the calibration period. Figure 7-6 compares the average monthly flows simulated by the model with observed average monthly flows. Figure 7-7 shows the simulated and observed flow frequency curves, and Figure 7-8 shows a representative storm. Each of these comparisons shows relatively good agreement between simulated and observed flows. This agreement indicates that the model developed for the Spout Run watershed represents the hydrologic conditions in the watershed and can be used to reasonably predict flows in Spout Run.

Table 7-14. Error Statistics for Hydrologic Calibration Period (2003-2008).

Statistics	Simulated (in/yr)	Observed (in/yr)	Error (%)	Criteria (%)	Criteria met
Total volume	14.94	14.46	3.33	10	Y
Volume of 50% lowest flows	3.64	3.79	-3.82	10	Y
Volume of 10% highest flows	4.45	4.18	6.50	15	Y
Seasonal volume - Summer	2.90	2.90	-0.17	30	Y
Seasonal volume - Fall	3.96	3.21	23.35	30	Y
Seasonal volume - Winter	4.76	4.18	13.71	30	Y
Seasonal volume - Spring	3.33	4.16	-20.11	30	Y
Total storm volume	1.31	1.13	16.04	20	Y
Summer storm volume	0.31	0.31	-2.32	50	Y
Coefficient of Determination (r^2)	0.6473				
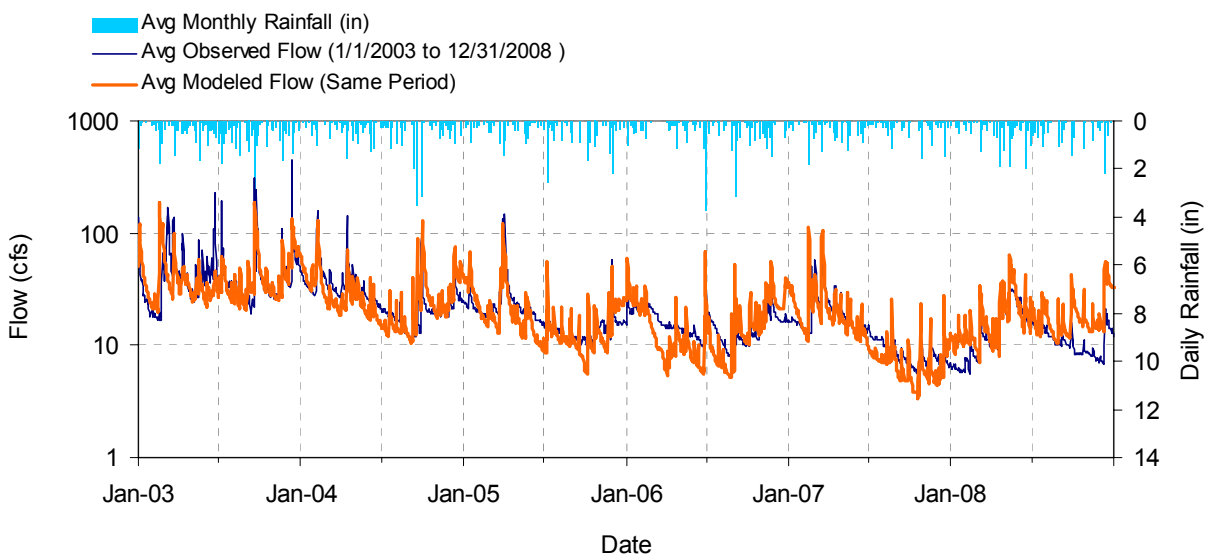
Figure 7-5. Simulated Versus Observed Flow in Spout Run During Calibration Period (2003-2008) – Log Scale.
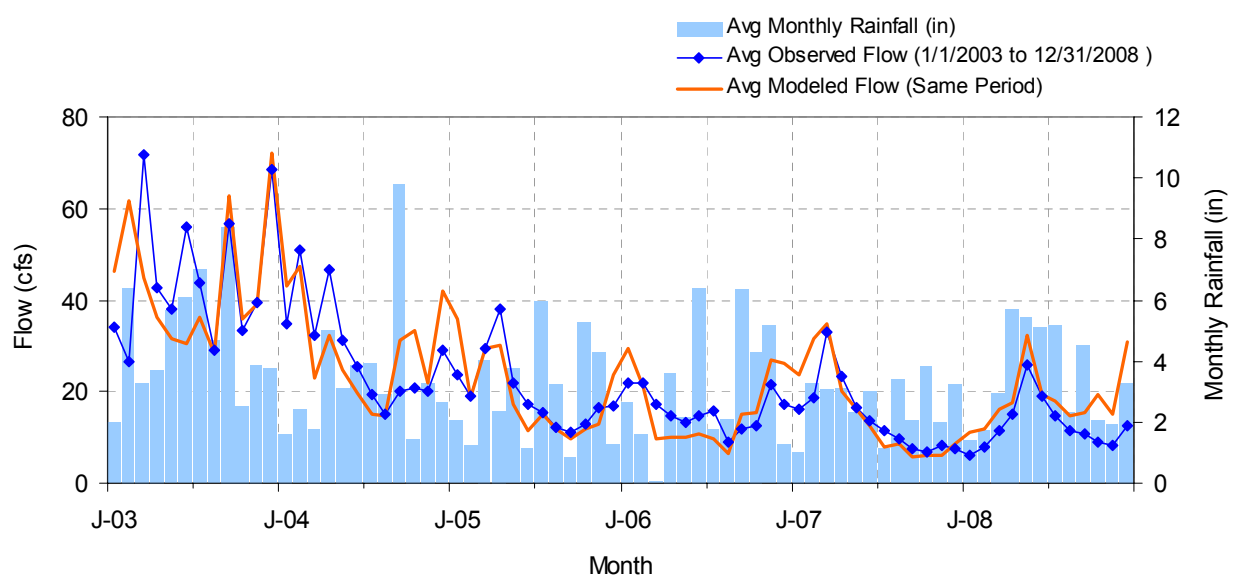
Figure 7-6. Simulated Versus Observed Average Monthly Flow in Spout Run During Calibration Period (2003-2008).
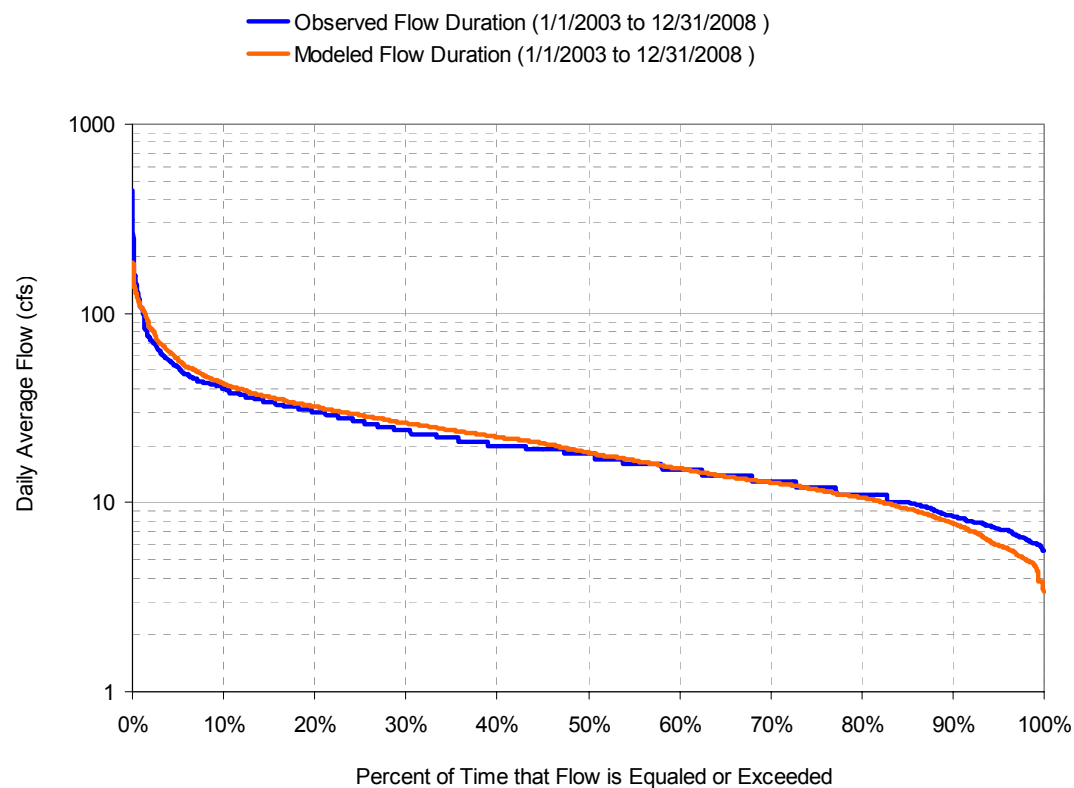
Figure 7-7. Simulated and Observed Flow Frequency Curves for Spout Run During the Calibration Period (2003-2008).
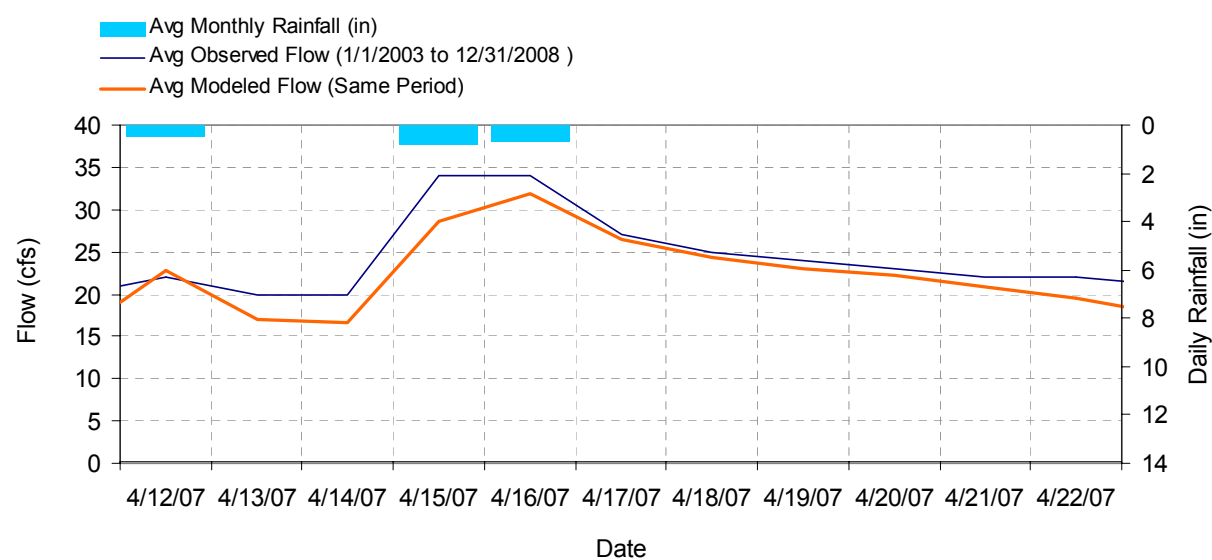
Figure 7-8. Representative Storm Event During Calibration Period (2003-2008).

7.7.2. Bacteria Calibration

To ensure that the LSPC model was accurately predicting bacteria concentrations in Spout Run, the water quality portion of the model was calibrated to observed fecal coliform monitoring data. Water quality was calibrated at the outlet of sub-watershed 19, which is the location of VADEQ's long-term monitoring station (1BSPR000.40). Since observed monitoring data spanned from 1991 to 2008, the 1991 to 1999 time period was used for water quality calibration and the 2000 to 2008 time period was used for validation of the bacteria model. During calibration, the water quality parameters identified in Table 7-6 were adjusted to obtain the best agreement between simulated fecal coliform concentrations and observed data. Final calibrated parameters are shown in APPENDIX B.

Table 7-15 compares statistics for simulated and observed fecal coliform concentrations during the calibration period. The calibrated model nicely fit observed fecal coliform data, matching the average and geometric mean to within about 5%. The simulated violation rate matched the observed rate to within approximately 1%. The observed fit easily met calibration criteria of 10%. Calibration criteria were not set for minimum and maximum values, since the monitoring data set is censored at the low and high end of the measurement range.

After calibration of the water quality parameters, the model was validated using a different time period of observed data. The time period from 2000 to 2008 was selected for model validation. Table 7-16 compares the simulated and observed fecal coliform statistics during the validation period. Similarly to the calibration period, good agreement was observed during the validation period. Average and geometric mean fecal coliform concentrations were within approximately 2% and 6%, respectively. Violation rates of the fecal coliform standard were within approximately 3% of observed rates.

The time series of simulated fecal coliform data in Spout Run is shown in Figure 7-9. It should be noted that exact agreement with observed data is not expected, because monitoring data represent a single snap-shot in time and simulated data represents a daily average concentration. While exact agreement is not expected, simulated results should match the range and pattern of observed fecal coliform data. During the calibration and validation periods, the range and pattern of observed fecal coliform data are matched nicely.

Table 7-15. Comparison of Simulated and Observed Fecal Coliform Statistics in Spout Run During the Calibration Period (1991-1999).

Statistic	Simulated	Observed	Error	Criteria	Criteria Met
min	8	100			
max	10956	2300			
average	485	461	5.36%		
geometric mean	255	270	-5.52%	10%	Y
violation rate	37.9%	36.8%	1.10%	10%	Y

Table 7-16. Comparison of Simulated and Observed Fecal Coliform Statistics in Spout Run During the Validation Period (2000-2008).

Statistic	Simulated	Observed	Error	Criteria	Criteria Met
min	12	100			
max	11035	3200			
average	307	300	2.17%		
geometric mean	189	178	6.05%	10%	Y
violation rate	22.0%	18.8%	3.24%	10%	Y
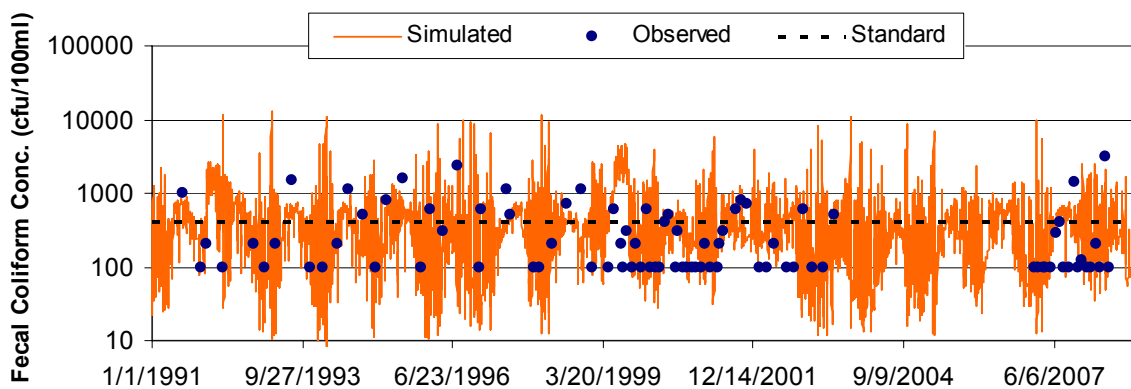
Figure 7-9.   Simulated Versus Observed Fecal Coliform Concentrations in the Spout Run Watershed.

Fecal coliform monitoring data exhibited a distinct seasonal pattern, with much higher violation rates during the summer and fall than the winter and spring (see Section 3.8.2). To determine if the Spout Run model exhibited this same seasonal pattern, simulated and observed monthly

violation rates were compared (Figure 7-10). In general, the model was able to match observed seasonal patterns in fecal coliform violation rates. For the majority of months, simulated monthly violation rates were within 5% of observed violation rates. Other months did not match as closely, however, this may be due to insufficient monthly monitoring data sets more than model error. For instance, only 6 monitoring data points were collected in October, the month that showed the largest difference between simulated and observed values. It is likely that those 6 data points are not representative of the month of October over an 18 year period.
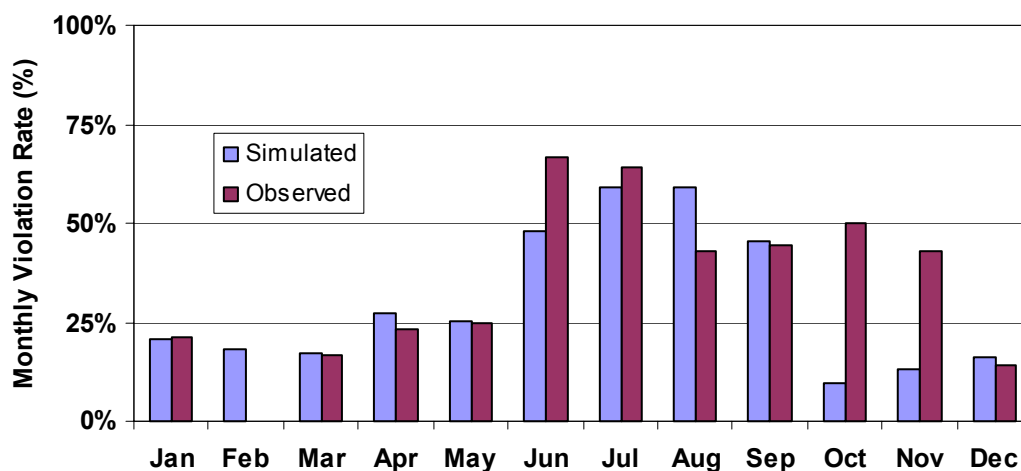
Figure 7-10. Simulated and Observed Seasonal Patterns of Bacteria Violation Rates in Spout Run.

Lastly, the bacteria model calibration was compared against spatial patterns of bacteria violation rates. Fecal coliform and *E. coli* monitoring data were collected in Page Brook and Roseville Run as well as in the Spout Run main stem (see Section 3.8). These data were compared to violation rates at the outlets of sub-watershed 6, 7, and 19, respectively. Simulated bacteria violation rates nicely matched observed monitoring data at all three locations (Figure 7-11). With the exception of fecal coliform at Roseville Run, simulated results were within 6% of observed violation rates. Fecal coliform results at Roseville Run differed by more than 10%, however, this may be due to limited monitoring data. Only 18 samples were available from

Roseville Run, compared to 30 and 86 from Page Brook and Spout Run, respectively. The fact that *E. coli* violations rates at Roseville Run matched within 4% also suggests that variations observed in fecal coliform results from this station are due to the representativeness of monitoring rather than model error.

In conclusion, the bacteria portion of the Spout Run model was successfully calibrated and validated. Bacteria statistics met all calibration and validation criteria, and simulated results matched all observed seasonal and spatial patterns. Based on the calibration results, it was determined that the Spout Run bacteria model was an acceptable tool for estimating TMDL loads and reduction scenarios in Spout Run.
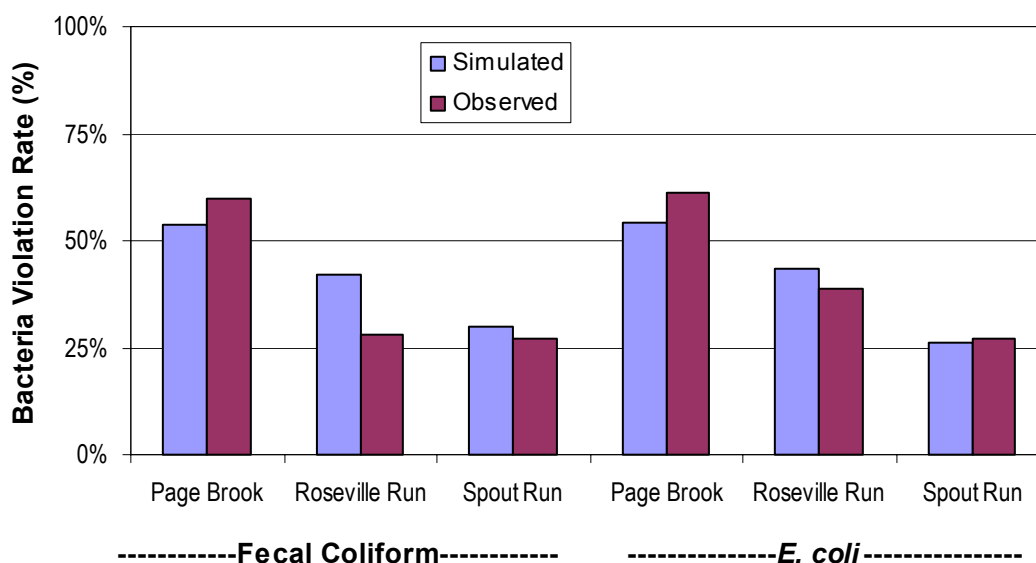
Figure 7-11. Simulated and Observed Spatial Patterns of Bacteria Violation Rates in the Spout Run Watershed.

7.7.3. GWLF Calibration

The GWLF model is designed for use in ungaged watersheds and does not require calibration. However, calibration of the model can improve model accuracy and model results, so the GWLF

model was calibrated against gaged Spout Run flow and calculated sediment loads from the measured sediment rating curve.

To calibrate the GWLF model for hydrology, simulated monthly flows for the watershed were compared to monthly flows calculated from the daily USGS flow gage records. Model parameters were adjusted to optimize the fit between observed and simulated flows. Figure 7-12 compares the observed and simulated monthly flow in Spout Run during the simulation period (4/1/2003 – 3/31/2008). The model was calibrated to closely match monthly flows throughout the modeling period.

Average monthly flows for the 5-year modeling period were also evaluated to calibrate GWLF parameters. Table 7-17 compares the observed and simulated average monthly flows for the 5-year modeling period. Following calibration, average simulated flow each month was within 12% of observed values. Total simulated flow was within 0.26% of observed flow.

In addition to hydrologic calibration, sediment transport in the Spout Run GWLF model was calibrated to match observed sediment fluxes in Spout Run. Based on observed flow and measured TSS values in Spout Run, a sediment rating curve was developed (Figure 7-13). This sediment rating curve was used in combination with the observed flow to calculate observed sediment loads in Spout Run during the modeling period. This calculation resulted in an average annual sediment flux of 236.7 T/yr. After calibration, the GWLF model yielded an annual sediment flux of 237.6 T/yr. This is within 0.38% of the calculated sediment yield. Overall, these results demonstrate that the GWLF model was appropriately calibrated to simulate hydrology and sediment transport in Spout Run.
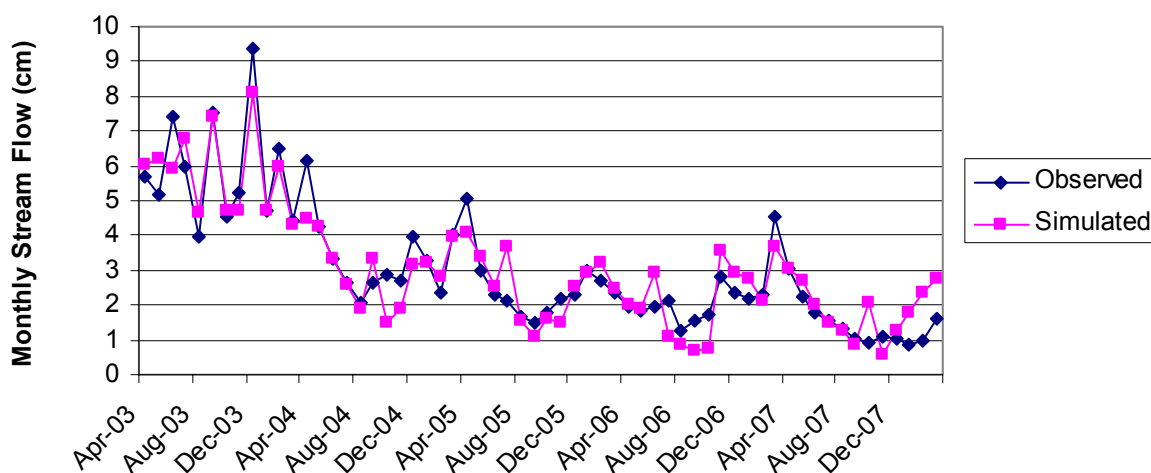
Figure 7-12. Observed and GWLF-modeled Monthly Stream Flow for Spout Run.

Table 7-17. Observed and GWLF-modeled Average Monthly Flows in Spout Run.

Month	Observed (cm)	Simulated (cm)	%error
Apr	4.38	3.93	-10.11%
May	3.30	3.69	11.85%
Jun	3.36	3.34	-0.67%
Jul	2.89	3.14	8.49%
Aug	2.06	2.06	0.23%
Sep	2.85	2.67	-6.20%
Oct	2.36	2.12	-10.07%
Nov	2.79	2.46	-11.84%
Dec	3.80	3.59	-5.51%
Jan	2.81	3.09	10.05%
Feb	2.97	3.31	11.50%
Mar	3.37	3.43	1.75%
Total	**36.93**	**36.84**	**-0.26%**
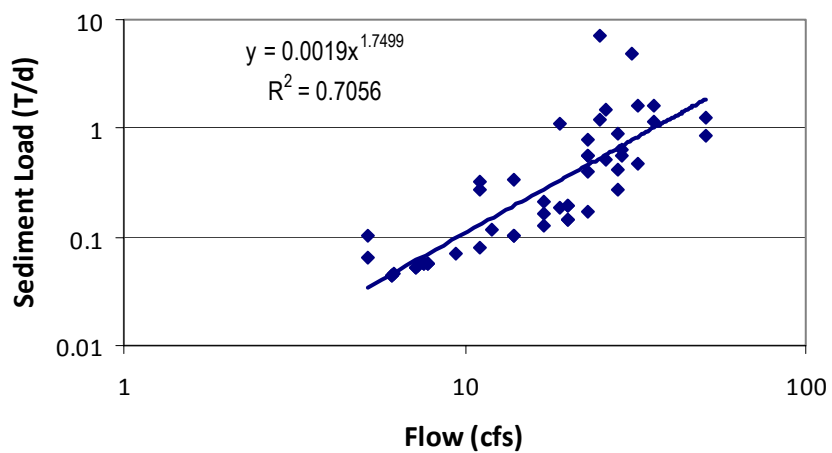
Figure 7-13. Sediment Rating Curve for Spout Run.

CHAPTER 8: TMDL ALLOCATIONS

The objective of a TMDL is to allocate allowable loads among different pollutant sources so that the appropriate control actions can be taken to achieve water quality standards (USEPA, 1991). To achieve this objective, existing conditions were first simulated and calibrated. Then future conditions were projected, and various reduction scenarios were adjusted until water quality standards were met.

8.1. EXISTING CONDITIONS

Following calibration of the Spout Run LSPC and GWLF models, the models were used to simulate existing conditions. Existing conditions were simulated using weather inputs for 2004 to 2008, source information described in Chapters 5 and 6, and calibrated model parameters. Since the GWLF model is based on April to April hydrologic years, existing conditions for the sediment model were simulated for April 2003 – March 2008.

8.1.1. Bacteria

Figure 8-1 shows the simulated concentrations of *E. coli* at the watershed outlet of Spout Run under existing conditions. Daily *E. coli* concentrations ranged from 11 to 4478 cfu/100ml and averaged 179 cfu/100ml. Monthly geometric mean *E. coli* concentrations ranged from 44 to 359 cfu/100ml and averaged 140 cfu/100ml. Daily concentrations exceeded the instantaneous target of 235 cfu/100ml 24% of the time, while monthly concentrations exceeded the geometric mean standard 48% of the time. Under existing conditions in Spout Run, the average annual *E. coli* load is 3.91 x 10^{13} cfu/yr.

E. coli concentrations were higher in Page Brook and Roseville Run (Figure 8-2 and Figure 8-3) than in Spout Run. In Page Brook, daily *E. coli* concentrations ranged from 11 to 4769 cfu/100ml and averaged 362 cfu/100ml. Daily concentrations exceeded the instantaneous target 52% of the time, while monthly concentrations exceeded the geometric mean standard 75% of the time. In Roseville Run, daily *E. coli* concentrations ranged from 7 to 4420 cfu/100ml and

averaged 241 cfu/100ml. Daily concentrations exceeded the instantaneous target 39% of the time, while monthly concentrations exceeded the geometric mean standard 53% of the time. Average annual *E. coli* loads were 1.67 x 10^{13} cfu/yr in Page Brook and 1.44 x 10^{13} cfu/yr in Roseville Run.

The calibrated LSPC model was used to determine the relative contributions of various sources to bacteria concentrations and bacteria loads in Spout Run. Each source was modeled individually, so that its contributions to the total loads could be evaluated. Table 8-1 summarizes this analysis. When all sources are combined, the instantaneous target and the geometric mean standard are violated 12% and 48% of the time, respectively. When sources are considered individually, only the direct deposit source from livestock is expected to cause violations of the geometric mean standard (21.67% of the time). This means that the livestock direct deposit source is the most important in controlling the *E. coli* geometric mean concentration. This observation is further illustrated in Figure 8-4. This figure shows the geometric mean *E. coli* concentrations that would be observed if only single sources were contributing. This figure demonstrates that direct deposits from livestock in the stream have the greatest contribution to monthly geometric mean *E. coli* concentrations. Straight pipes are the next largest contributor, followed by residential/urban runoff and wildlife direct deposits. The largest peaks in monthly *E. coli* geometric mean concentrations occur during the summer months when flows are the lowest. At these times, the contributions from livestock direct deposit account for the majority of the concentration. During wetter periods, however, other sources such as straight pipes or residential lands have larger contributions. This figure also shows that point sources and runoff from agricultural and forest lands are the smallest contributors to monthly *E. coli* geometric mean concentrations. This does not imply that these sources have insignificant bacteria contributions. Agricultural lands, for example, have large bacteria loads, however, those loads only contribute during runoff events. Because most months only include several days of runoff, the contribution of agricultural lands to instream geometric mean concentrations is low.

Table 8-1 also shows the contributions of individual sources to violations of the instantaneous *E. coli* target of 235 cfu/100ml. All sources combined cause a 24% violation rate of the instantaneous target. Individually, agricultural runoff causes the highest violation rate (6.95%), followed closely by livestock direct deposits (with 5.80%). Residential runoff also individually

caused instantaneous violations (0.27%). Straight pipes, wildlife direct deposit, point sources, and forest runoff individually are not predicted to cause any violations of the instantaneous target.

While livestock direct deposits have the greatest impact on instream *E. coli* concentrations, agricultural runoff has the greatest impact when considering annual loads of *E. coli* to the stream (Table 8-1). Agricultural runoff accounts for more than 56% of the total annual load of *E. coli*, livestock direct deposit accounts for 23%, residential and urban runoff account for 12%, straight pipes account for 7%, wildlife direct deposit accounts for 2%, and all other sources account for less than 1% of total annual *E. coli* loads (Figure 8-5). There are several reasons that agricultural runoff accounts for such a high percentage of the total annual *E. coli* load but a much smaller proportion of the instream concentration. Flows are greatly increased during runoff events, so *E. coli* loads are large, but those loads only effect instream concentrations during precipitation events. During most of the year, it is not raining, so day-to-day instream concentrations are much more controlled by continuous sources, such as livestock direct deposit.
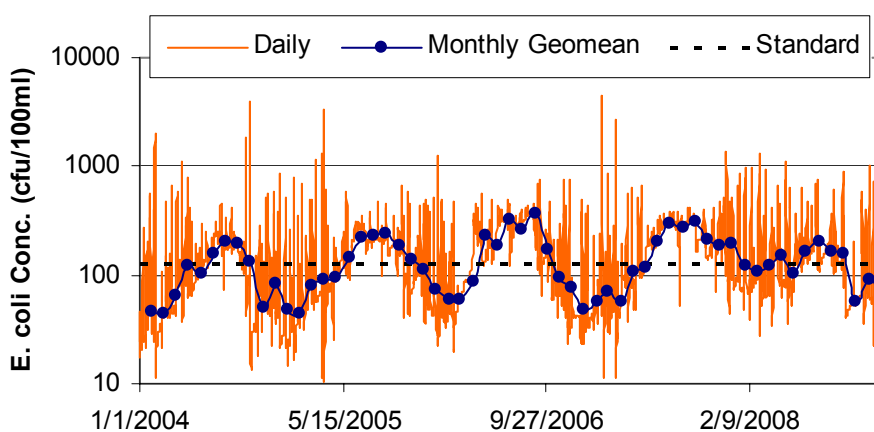
Figure 8-1. ***E. coli*** **Concentrations in Spout Run Under Existing Conditions.**
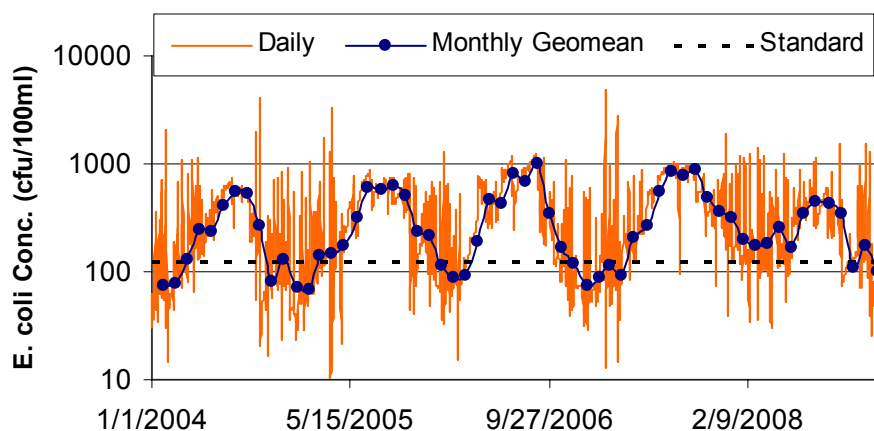
Figure 8-2. *E. coli* Concentrations in Page Brook Under Existing Conditions.
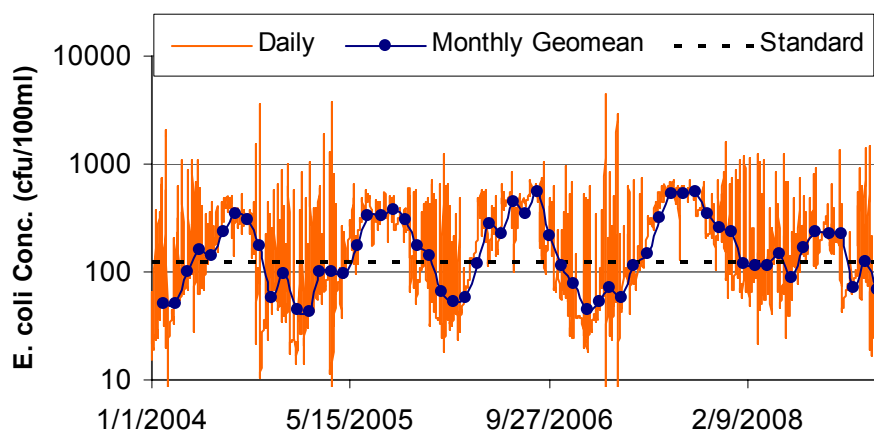
Figure 8-3. E. coli Concentrations in Roseville Run Under Existing Conditions.

Table 8-1. Relative Contributions of Various Bacteria Sources Under Existing Conditions.

Statistic	Straight Pipes	Livestock DD	Wildlife DD	Point Sources	Res/Urban Runoff	Ag Runoff	Forest Runoff	All
Geo mean Violation Rate	0.00%	21.67%	0.00%	0.00%	0.00%	0.00%	0.00%	48.33%
Instantaneous Violation Rate	0.00%	5.80%	0.00%	0.00%	0.27%	6.95%	0.00%	23.86%
Average Annual Load	2.72E+12	9.66E+12	6.21E+11	1.10E+10	4.77E+12	2.32E+13	6.38E+10	4.10E+13
Percent of Total Annual Load	6.62%	23.55%	1.51%	0.03%	11.62%	56.52%	0.16%	100.00%
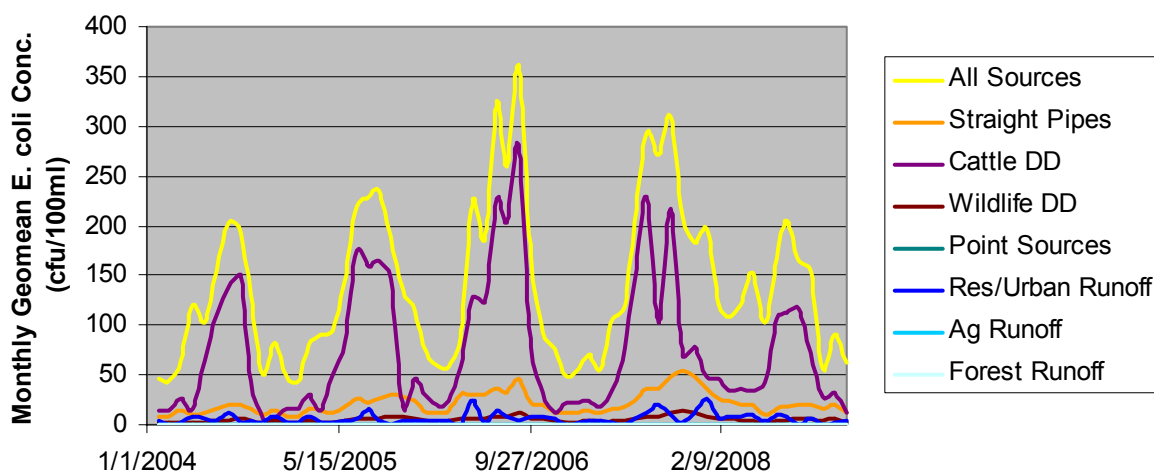
Figure 8-4. Relative Contributions of Various Sources to the Monthly Geometric Mean *E. coli* Concentration in Spout Run Under Existing Conditions.
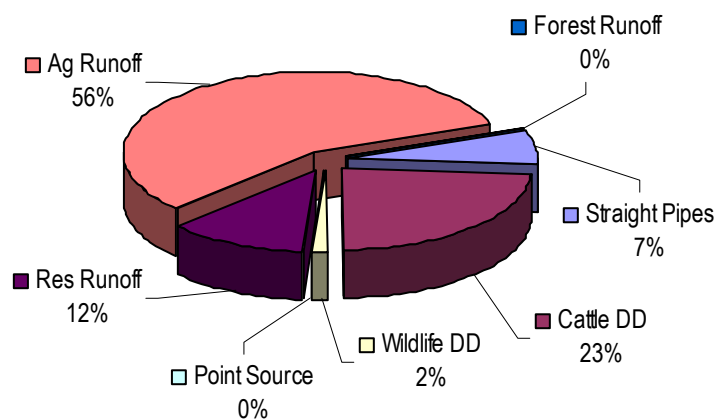
Figure 8-5. Relative Contributions of Various Bacteria Sources to Spout Run *E. coli* Loads Under Existing Conditions.

8.1.2. Suspended Sediment

The GWLF sediment model simulated monthly erosion and sediment loadings in Spout Run under existing conditions (April 2003 – April 2008). Figure 8-6 shows the monthly sediment loads simulated in Spout Run. Monthly loads ranged from 5.0 T/mo in November 2007 to 104

T/mo in September 2004. The month with the highest sediment load corresponds to the timing of back-to-back hurricanes Frances, Ivan, and Jeanne. Monthly sediment loads under existing conditions averaged 19.8 T/mo.
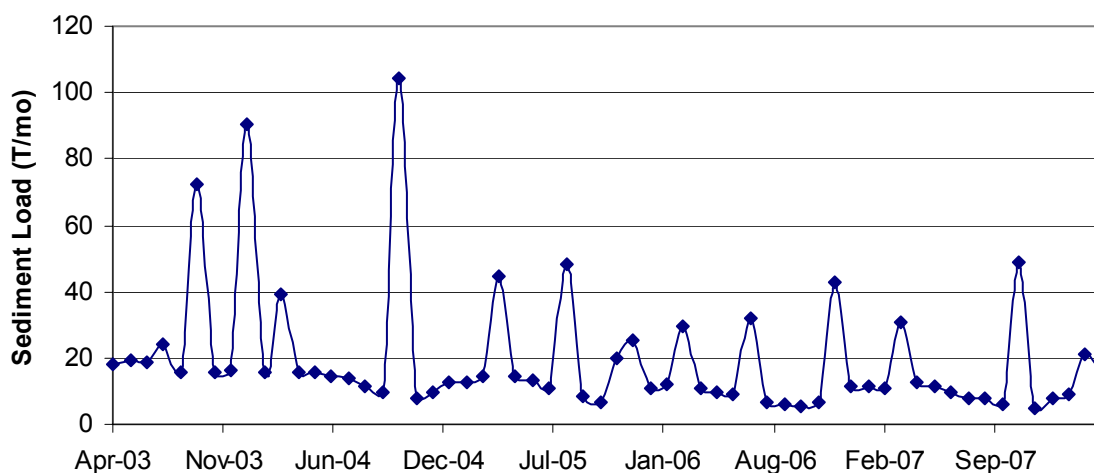
Figure 8-6. Simulated Monthly Sediment Loads in Spout Run Under Existing Conditions.

Table 8-2. Annual Sediment Loads in Spout Run Under Existing Conditions.

Year[1]	Sediment Load (T/yr)
2004	362
2005	271
2006	210
2007	183
2008	162
Average	238
Min	162
Max	362
Total	1188

[1] Years are recorded from April to April, and year recorded represents the ending date.

 Annual sediment loads for the 5-year period representing existing conditions are shown in Table 8-2. Annual loads ranged from 162 – 362 T/yr and averaged 238 T/yr. As described in Section 6.2, sediment loads were dominated by stream bank erosion. On average, stream bank erosion contributed 141 of the 238 T/yr of sediment (Table 8-3). Degraded riparian pasture contributed

the next highest amount (51.1 T/yr), followed by pasture (27.3 T/yr) and cropland (8.22 T/yr). Other sources had relatively small contributions to annual sediment loads.

Table 8-3. Annual Sediment Loads from Various Sources Under Existing Conditions.

Land Use	Annual Sediment Load (T/yr)
Residential/Urban	1.76
Crop	8.22
Pasture	27.3
Degraded Riparian Pasture	51.1
Forest	2.77
Transitional	5.54
Point Sources	0.251
Bank erosion	141
Total	**238**

8.2. FUTURE CONDITIONS

The Spout Run TMDL was developed to consider further growth and future conditions in the watershed. TMDLs do impose caps on the amount of pollutants discharged in a watershed, however, the reductions called for in the TMDL may take several years to achieve. Changes in populations and land use are likely to continue as the TMDL is being implemented, so the TMDL considers those changes. For the Spout Run TMDL, a projection of future conditions in the year 2020 was used. 2020 represents a reasonable time frame for this TMDL to be implemented.

For future condition projections, the county comprehensive plan for Clarke County was consulted (Clarke County, 2007). The county comprehensive plan projected population increases of 17.1% from 2010 to 2020. This value was used to estimate land use changes in the watershed. Residential and urban/transportation land uses were increased by 17.1% in each sub-watershed, resulting in a conversion of 188 acres. To offset increases in these residential and urban/transportation land uses, area-weighted decreases were made to pasture, cropland, and forest land uses. Table 8-4 shows the projected changes in land use for each sub-watershed.

Overall, 188 acres are projected to be converted from forest, pasture, or cropland to residential or urban/transportation over the next 10 years.

Assuming that the 188 acres of land converted to residential or urban/transportation uses is developed gradually over the 10 years and each development project has an average of a 2 year life span, 38 acres are estimated to be in transition each year. Since this is less than the current estimated transitional land uses (51 acres), no change in transitional land uses were made under the future conditions scenario.

Table 8-4. Projected Future Growth Land Uses Changes in the Spout Run Watershed.

Sub-watershed	Change in Land Use Acreage (acres)				
	Impervious Urban/ Transportation	Residential	Forest	Pasture/Hay	Cropland
1	+3	+2	-2	-2	0
2	0	0	0	0	0
3	+2	+7	-4	-4	0
4	+2	+2	-1	-3	0
5	+9	+29	-9	-28	-1
6	+1	+4	-1	-4	0
7	+6	+16	-3	-19	0
8	0	+1	-1	0	0
9	+5	+22	-4	-23	0
10	+7	+11	-4	-14	0
11	+5	+9	-4	-10	0
12	0	0	0	0	0
13	+3	+2	-1	-4	0
14	+1	+3	-1	-2	0
15	+4	+9	-5	-7	0
16	+5	+9	-4	-10	-1
17	+3	+4	-2	-5	0
18	0	0	0	0	0
19	0	0	-1	0	0
20	0	0	0	0	0
Total	**56**	**132**	**-49**	**-136**	**-3**

8.3. BACTERIA TMDL

LSPC model simulations for 2004 to 2008 were used to develop TMDL allocations. This period was selected for allocation determination because it represents a range of flows, it corresponds to the period of gaged stream flow, and it corresponds to the most recent conditions in the watershed.

The objective of the bacteria TMDL for Spout Run is to determine what reductions in fecal coliform and *E. coli* loadings from point and nonpoint sources are required to meet state water quality standards. The state water quality standard for *E. coli* used in the development of this TMDL was a calendar-month geometric mean of 126 cfu/100mL. In addition, the TMDL was set to meet an instantaneous target of 235 cfu/100mL with a violation rate of less than 10.5%. Since monitoring is traditionally not conducted at a frequency sufficient to calculate monthly geometric means, assessment of the bacteria water quality standard is based on a less than 10.5% violation rate of the instantaneous target of 235 cfu/100mL.

Because Page Brook, Roseville Run, and Spout Run all currently exceed the bacteria water quality standard, TMDLs were developed for each stream individually. Reductions in the upstream tributaries (Page Brook and Roseville Run) were set first in order to meet water quality standards at the outlet of those sub-watersheds. For the Spout Run TMDL, those upstream reductions were maintained, and additional reductions for the remainder of the Spout Run watershed (if necessary) were then set to meet water quality standards at the outlet of Spout Run.

The TMDL considers all sources contributing fecal coliform and *E. coli* to Page Brook, Roseville Run, and Spout Run, including point (or direct) and nonpoint (or indirect) sources. The TMDL can be shown to represent these sources as defined in the following equation:

$$\text{TMDL} = \text{WLA} + \text{LA} + \text{MOS} \qquad\qquad [8\text{-}1]$$

where,

WLA = wasteload allocation (point source contributions);

LA   = load allocation (nonpoint source contributions); and

MOS = margin of safety.

In the Page Brook, Roseville Run, and Spout Run TMDLs, an implicit margin of safety (MOS) was included. Implicit margins of safety are implemented by using conservative estimates of model input parameters and by using a conservative calibration of water quality (bacteria) parameters. Developing a TMDL based on conservative estimates and a conservative calibration provides an implicit allowance for uncertainty.

8.3.1. Page Brook

To develop the bacteria TMDL for Page Brook, bacteria reductions in sub-watersheds 1-6 were set to meet bacteria water quality standards at the outlet of sub-watershed 6 (Page Brook). This section describes the TMDL for Page Brook.

8.3.1.1. Allocation Scenarios

A variety of allocation scenarios were evaluated to meet the *E. coli* TMDL goal of a calendar-month geometric mean of 126 cfu/100mL and a violation rate of less than 10.5% for the instantaneous target of 235 cfu/100mL. Each scenario represents a different combination of bacteria load reductions from the various sources. These load reductions were modeled by decreasing the amount of bacteria applied to the land surface or directly deposited in the stream. In the model, this has the effect of reducing the amount of bacteria that reaches the stream, the ultimate goal of the TMDL. Thus, the reductions called for in the various scenarios indicate the need to decrease the amount of bacteria reaching the stream in order to meet the applicable water quality standard. The reductions are not intended to infer that agricultural producers should reduce their herd size or limit the use of manure as fertilizer or soil conditioner. Rather, it is assumed that the required reductions from affected agricultural source categories (cattle direct deposit, cropland, etc.) will be accomplished by implementing BMPs like filter strips, stream fencing, and off-stream watering; and that required reductions from residential source categories will be accomplished by repairing aging septic systems, eliminating straight pipe discharges, and other appropriate measures included in the TMDL Implementation Plan.

Various allocation scenarios for the Page Brook watershed are summarized in Table 8-5. The first scenario represents the future condition described in Section 8.2. This scenario produces a

73% violation rate of the geometric mean standard and a 51% violation rate of the instantaneous target. The second scenario evaluates the results of eliminating anthropogenic sources of bacteria. This scenario demonstrates that the TMDL can be met without reductions in wildlife direct deposit or forest runoff. Scenario 3 shows the results of eliminating straight pipes, which makes only small improvements in *E. coli* violation rates. Because straight pipes are illegal and must be corrected if identified, all remaining scenarios contain 100% reductions in straight pipes, even though those reductions have small impacts on overall violation rates.

The next several scenarios (4-6) show the results of eliminating bacteria from cattle direct deposit, agricultural runoff, and residential runoff, respectively. Of these three, elimination of cattle direct deposits had the largest impact on violation rates, but elimination of any of these sources independently would not be enough to meet the TMDL. Scenario 7 shows the results of making modest reductions in each of these sources simultaneously. Once again, these reductions were not enough to meet the water quality standard. Scenarios continued to make reductions in these sources until the water quality standard was met. Scenario 9 shows that 90% reductions in cattle direct deposit, agricultural runoff, and residential runoff (in combination with the elimination of straight pipes) would be necessary to meet the geometric mean standard and reduce violations of the instantaneous target to below 10.5%. Scenario 9, therefore, would be an acceptable reduction scenario for the TMDL.

In order to provide additional TMDL options, scenarios 10, 11 and 12 attempted to increase the reductions on cattle direct deposits and thereby decrease the necessary reductions required for runoff sources. Because cattle direct deposits represent the largest bacteria source and because reductions from this source are often the most cost effective, it is reasonable to set reduction levels for this source higher than other sources. Scenario 10 shows that if cattle direct deposits are reduced by 91%, only 75% reductions are needed from agricultural and residential/urban runoff sources. In scenario 11, cattle direct deposit reductions are raised to 92% and reductions from runoff sources are dropped to 50%. Scenario 12 sets 50% reductions for agricultural runoff, but maintains equity between cattle direct deposit and residential/urban runoff sources (91% reduction). These scenarios demonstrate the strong influence of direct deposits on instream *E. coli* concentrations.

In summary, scenarios 9, 10, 11, and 12 represent successful scenarios that could be selected for the TMDL. Based on discussion among the Local Steering Committee, scenario 12 was ultimately selected as the TMDL scenario, because it maintains some equity between agricultural and residential source reductions. The Local Steering Committee felt that it was important for different sources to shoulder equal burdens during TMDL implementation. While the numerical TMDL was developed based on this scenario (12), the remaining successful scenarios (9, 10 and 11) could also be acceptable choices during implementation planning if the implementation planning team determined that one of these scenarios would be preferable.

Table 8-5. Bacteria Allocation Scenarios for Page Brook.

Scenario[1]	Fecal Coliform Loading Reductions (%)							% Violation of *E. coli* Standard		Average Annual *E. coli* Load (cfu/yr)
	Straight Pipes	Cattle DD	Wildlife DD	Permitted Point Sources	Agricultural Runoff	Residential/ Urban Runoff	Forest Runoff	Geometric Mean	Instantane-ous	
Future Condition	0%	0%	0%	0%	0%	0%	0%	73.33%	51.34%	1.68E+13
2	100%	100%	0%	0%	100%	100%	0%	0.00%	0.00%	4.30E+11
3	100%	0%	0%	0%	0%	0%	0%	68.33%	50.19%	1.63E+13
4	100%	100%	0%	0%	0%	0%	0%	0.00%	12.10%	1.01E+13
5	100%	0%	0%	0%	100%	0%	0%	61.67%	41.93%	8.34E+12
6	100%	0%	0%	0%	0%	100%	0%	66.67%	47.07%	1.49E+13
7	100%	50%	0%	0%	50%	50%	0%	46.67%	29.34%	8.76E+12
8	100%	80%	0%	0%	80%	80%	0%	11.67%	2.03%	3.98E+12
9	100%	90%	0%	0%	90%	90%	0%	0.00%	0.22%	2.28E+12
10	100%	91%	0%	0%	75%	75%	0%	0.00%	2.03%	3.73E+12
11	100%	92%	0%	0%	50%	50%	0%	0.00%	6.73%	6.06E+12
12	100%	91%	0%	0%	50%	91%	0%	0.00%	5.31%	5.53E+12

[1] Scenarios highlighted in yellow represent reduction levels that the geometric mean standard and meet a 10.5% violation rate of the instantaneous *E. coli* target. These represent acceptable scenarios for defining the TMDL.

Under the TMDL scenario, the average annual *E. coli* load is 5.53 x 10^{12} cfu/yr, which is a 67% reduction in the average annual *E. coli* load of 1.67 x 10^{13} under existing conditions. Figure 8-7 shows the resulting *E. coli* concentrations under the TMDL scenario. Monthly geometric means are below the water quality standard of 126 cfu/100mL for the entire simulation period. This demonstrates that the TMDL scenario is protective of the recreational designated use of Page Brook.
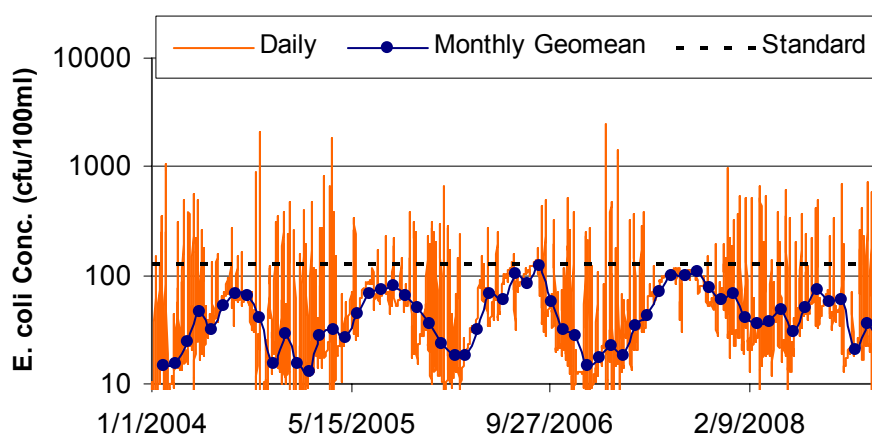
Figure 8-7. *E. coli* **Concentrations in Page Brook Under Successful TMDL Conditions.**

8.3.1.2. Wasteload Allocation

The wasteload allocation (or WLA) portion of a TMDL includes the contributions from permitted point sources in the watershed. Within the Page Brook watershed, there are currently no point sources permitted to discharge fecal bacteria. In order to allow for future growth and the possibility of future permitted dischargers in the watershed, a future growth wasteload allocation was apportioned for the Page Brook watershed. This allocation was determined as one half of the future growth allocation for the entire Spout Run watershed. Within the Spout Run watershed, there is one point source permitted to discharge fecal bacteria (the Boyce STP). DEQ guidance for bacteria TMDL development recommends adding a future growth wasteload allocation of 5 times the existing wasteload allocation. For Spout Run, this 5-times allocation

was split evenly between the Page Brook and Roseville Run watersheds. Since the existing permitted flow of the Boyce STP is 0.05 MGD, a future growth flow of 0.125 MGD (2.5 times the existing flow) was added to both the Page Brook and Roseville Run watersheds. For Page Brook, this resulted in an annual *E. coli* wasteload allocation of 2.18 x 10^{11} cfu/yr and a daily *E. coli* wasteload allocation of 5.96 x 10^{8} cfu/d (Table 8-6).

Table 8-6. Wasteload Allocation Table for the Page Brook TMDL.

Facility	Permit #	Permitted Flow (MGD)	Permitted *E. coli* Conc. (cfu/100mL)	Annual *E. coli* WLA (cfu/yr)	Daily *E. coli* WLA (cfu/d)
Future Growth	NA	0.125	126	2.18E+11	5.96E+08
Total		0.125	126	2.18E+11	5.96E+08

8.3.1.3. TMDL Expression

The TMDL for Page Brook was derived from allocation scenario 12 (Table 8-5). Under this scenario, the TMDL was calculated as 5.53 x 10^{12} cfu/yr. Table 8-7 provides the TMDL equation for Page Brook expressed on an average annual basis. This TMDL includes a WLA for permitted point sources (including a future growth factor), a load allocation (LA) for non-point sources, and an implicit margin of safety.

Table 8-7. Total Maximum Daily Load of *E. coli* for Page Brook Expressed as an Average Annual Load.

Stream	WLA (cfu/yr)	LA (cfu/yr)	MOS	TMDL (cfu/yr)
Page Brook	2.18E+11	5.31E+12	Implicit	5.53E+12

In order to comply with current USEPA guidance (USEPA, 2007), the Page Brook bacteria TMDL was also expressed as a daily load by evaluating the variability and distribution of simulated loads (Table 8-8). Because the LSPC model produces continuous simulation results during the modeling period, the distribution of daily *E. coli* loads under the TMDL scenario

could be used to derive the daily expression of the TMDL. The 95th percentile daily *E. coli* load was selected to represent the daily TMDL expression.

Table 8-8. Total Maximum Daily Load of *E. coli* for Page Brook Expressed as a Daily Load.

Stream	WLA[1] (cfu/d)	LA (cfu/d)	MOS	TMDL[2] (cfu/d)
Page Brook	5.96E+08	4.92E+10	Implicit	4.98E+10

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

[2] The TMDL is presented for the 95th percentile daily *E. coli* load simulated under the TMDL scenario.

8.3.2. Roseville Run

To develop the bacteria TMDL for Roseville Run, bacteria reductions in sub-watersheds 7-14 were set to meet bacteria water quality standards at the outlet of sub-watershed 14 (Roseville Run). This section describes the TMDL for Roseville Run.

8.3.2.1. Allocation Scenarios

A variety of allocation scenarios were evaluated to meet the *E. coli* TMDL goal of a calendar-month geometric mean of 126 cfu/100mL and a violation rate of less than 10.5% for the instantaneous target of 235 cfu/100mL. Each scenario represents a different combination of bacteria load reductions from the various sources. These load reductions were modeled by decreasing the amount of bacteria applied to the land surface or directly deposited in the stream. In the model, this has the effect of reducing the amount of bacteria that reaches the stream, the ultimate goal of the TMDL. Thus, the reductions called for in the various scenarios indicate the need to decrease the amount of bacteria reaching the stream in order to meet the applicable water quality standard. The reductions are not intended to infer that agricultural producers should reduce their herd size or limit the use of manure as fertilizer or soil conditioner. Rather, it is assumed that the required reductions from affected agricultural source categories (cattle direct deposit, cropland, etc.) will be accomplished by implementing BMPs like filter strips, stream fencing, and off-stream watering; and that required reductions from residential source categories

will be accomplished by repairing aging septic systems, eliminating straight pipe discharges, and other appropriate measures included in the TMDL Implementation Plan.

Various allocation scenarios for the Roseville Run watershed are summarized in Table 8-9. The first scenario represents the future condition described in Section 8.2. This scenario produces a 57% violation rate of the geometric mean standard and a 36% violation rate of the instantaneous target. The second scenario evaluates the results of eliminating anthropogenic sources of bacteria. This scenario demonstrates that the TMDL can be met without reductions in wildlife direct deposit or forest runoff. Scenario 3 shows the results of eliminating straight pipes, which makes only small improvements in *E. coli* violation rates. Because straight pipes are illegal and must be corrected if identified, all remaining scenarios contain 100% reductions in straight pipes, even though those reductions have small impacts on overall violation rates.

The next several scenarios (4-6) show the results of eliminating bacteria from cattle direct deposit, agricultural runoff, and residential runoff, respectively. Of these three, elimination of cattle direct deposits had the largest impact on violation rates, but elimination of any of these sources independently would not be enough to meet the TMDL. Scenario 7 shows the results of making modest reductions in each of these sources simultaneously. Once again, these reductions were not enough to meet the water quality standard. Scenarios continued to make reductions in these sources until the water quality standard was met. Scenario 9 shows that 83% reductions in cattle direct deposit, agricultural runoff, and residential runoff (in combination with the elimination of straight pipes) would be necessary to meet the geometric mean standard and reduce violations of the instantaneous target to below 10.5%. Scenario 9, therefore, would be an acceptable reduction scenario for the TMDL.

In order to provide additional TMDL options, scenarios 10, 11, and 12 attempted to increase the reductions on cattle direct deposits and thereby decrease the necessary reductions required for runoff sources. Because cattle direct deposits represent the largest bacteria source and because reductions from this source are often the most cost effective, it is reasonable to set reduction levels for this source higher than other sources. Scenario 10 shows that if cattle direct deposits are reduced by 85%, only 75% reductions are needed from agricultural and residential/urban runoff sources. In scenario 11, cattle direct deposit reductions are raised to 90% and reductions

from runoff sources are dropped to 50%. Scenario 12 sets 50% reductions for agricultural runoff, but maintains equity between cattle direct deposit and residential/urban runoff sources (83% reduction). These scenarios demonstrate the strong influence of direct deposits on instream *E. coli* concentrations.

In summary, scenarios 9, 10, 11, and 12 represent successful scenarios that could be selected for the TMDL. Based on discussion among the Local Steering Committee, scenario 12 was ultimately selected as the TMDL scenario, because it maintains some equity between agricultural and residential source reductions. The Local Steering Committee felt that it was important for different sources to shoulder equal burdens during TMDL implementation. While the numerical TMDL was developed based on this scenario (12), the remaining successful scenarios (9, 10 and 11) could also be acceptable choices during implementation planning if the implementation planning team determined that one of these scenarios would be preferable.

Table 8-9. Bacteria Allocation Scenarios for Roseville Run.

Scenario[1]	Fecal Coliform Loading Reductions (%)							% Violation of *E. coli* Standard		Average Annual *E. coli* Load (cfu/yr)
	Straight Pipes	Cattle DD	Wildlife DD	Permitted Point Sources	Agricultural Runoff	Residential/ Urban Runoff	Forest Runoff	Geometric Mean	Instantane-ous	
Future Condition	0%	0%	0%	0%	0%	0%	0%	56.67%	36.18%	1.46E+13
2	100%	100%	0%	0%	100%	100%	0%	0.00%	0.00%	6.72E+11
3	100%	0%	0%	0%	0%	0%	0%	48.33%	29.89%	1.39E+13
4	100%	100%	0%	0%	0%	0%	0%	0.00%	14.78%	1.17E+13
5	100%	0%	0%	0%	100%	0%	0%	40.00%	20.36%	4.87E+12
6	100%	0%	0%	0%	0%	100%	0%	38.33%	21.78%	1.21E+13
7	100%	50%	0%	0%	50%	50%	0%	25.00%	12.37%	7.61E+12
8	100%	80%	0%	0%	80%	80%	0%	6.67%	1.37%	3.62E+12
9	100%	83%	0%	0%	83%	83%	0%	0.00%	0.77%	3.20E+12
10	100%	85%	0%	0%	75%	75%	0%	0.00%	1.92%	4.08E+12
11	100%	90%	0%	0%	50%	50%	0%	0.00%	7.06%	6.72E+12
12	100%	83%	0%	0%	50%	83%	0%	0.00%	5.36%	6.27E+12

[1] Scenarios highlighted in yellow represent reduction levels that the geometric mean standard and meet a 10.5% violation rate of the instantaneous *E. coli* target. These represent acceptable scenarios for defining the TMDL.

Under the TMDL scenario, the average annual *E. coli* load is 6.27 x 10^{12} cfu/yr, which is a 56% reduction in the average annual *E. coli* load of 1.44 x 10^{13} under existing conditions. Figure 8-8 shows the resulting *E. coli* concentrations under the TMDL scenario. Monthly geometric means are below the water quality standard of 126 cfu/100mL for the entire simulation period. This demonstrates that the TMDL scenario is protective of the recreational designated use of Roseville Run.
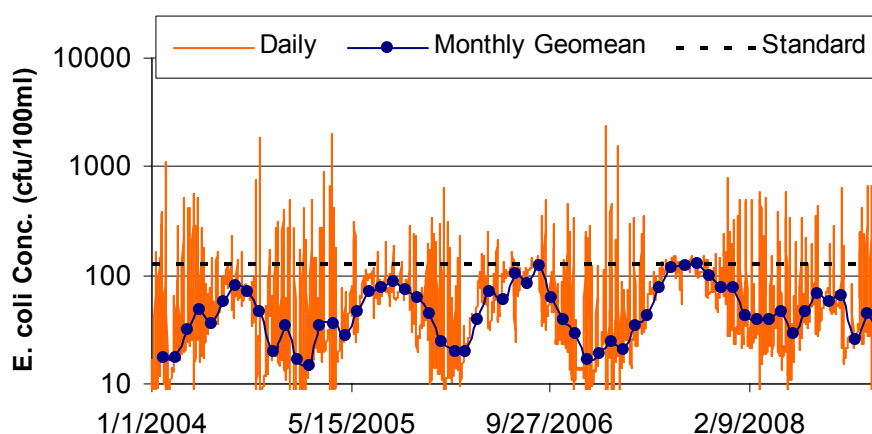
Figure 8-8. *E. coli* **Concentrations in Roseville Run Under Successful TMDL Conditions.**

8.3.2.2. Wasteload Allocation

The wasteload allocation (or WLA) portion of a TMDL includes the contributions from permitted point sources in the watershed. Within the Roseville Run watershed, the Boyce STP is currently the only point source permitted to discharge fecal bacteria. The Boyce STP is permitted to discharge up to 0.05 MGD of treated wastewater with an *E. coli* concentration of 126 cfu/100mL. In order to allow for future growth, an additional wasteload allocation was apportioned for the Roseville Run watershed. This allocation was determined as one half of the future growth allocation for the entire Spout Run watershed. DEQ guidance for bacteria TMDL development recommends adding a future growth wasteload allocation of 5 times the existing wasteload allocation. For Spout Run, this 5-times allocation was split evenly between the Page

Brook and Roseville Run watersheds. Since the existing permitted flow of the Boyce STP is 0.05 MGD, a future growth flow of 0.125 MGD (2.5 times the existing flow) was added to both the Page Brook and Roseville Run watersheds. For Roseville Run, the existing wasteload plus the additional future growth resulted in an annual *E. coli* wasteload allocation of 3.05×10^{11} cfu/yr and a daily *E. coli* wasteload allocation of 8.35×10^{8} cfu/d (Table 8-10).

Table 8-10. Wasteload Allocation Table for the Roseville Run TMDL.

Facility	Permit #	Permitted Flow (MGD)	Permitted *E. coli* Conc. (cfu/100mL)	Annual *E. coli* WLA (cfu/yr)	Daily *E. coli* WLA (cfu/d)
Boyce STP	VA0085171	0.05	126	8.70E+10	2.38E+08
Future Growth	NA	0.125	126	2.18E+11	5.96E+08
Total		0.175	126	3.05E+11	8.35E+08

8.3.2.3. TMDL Expression

The TMDL for Roseville Run was derived from allocation scenario 12 (Table 8-9). Under this scenario, the TMDL was calculated as 6.27×10^{12} cfu/yr. Table 8-11 provides the TMDL equation for Roseville Run expressed on an average annual basis. This TMDL includes a WLA for permitted point sources (including a future growth factor), a load allocation (LA) for non-point sources, and an implicit margin of safety.

Table 8-11. Total Maximum Daily Load of *E. coli* for Roseville Run Expressed as an Average Annual Load.

Stream	WLA (cfu/yr)	LA (cfu/yr)	MOS	TMDL (cfu/yr)
Roseville Run	3.05E+11	5.97E+12	Implicit	6.27E+12

In order to comply with current USEPA guidance (USEPA, 2007), the Roseville Run bacteria TMDL was also expressed as a daily load by evaluating the variability and distribution of simulated loads (Table 8-12). Because the LSPC model produces continuous simulation results during the modeling period, the distribution of daily *E. coli* loads under the TMDL scenario

could be used to derive the daily expression of the TMDL. The 95th percentile daily *E. coli* load was selected to represent the daily TMDL expression.

Table 8-12. Total Maximum Daily Load of *E. coli* for Roseville Run Expressed as a Daily Load.

Stream	WLA[1] (cfu/d)	LA (cfu/d)	MOS	TMDL[2] (cfu/d)
Roseville Run	8.35E+08	5.46E+10	Implicit	5.55E+10

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2] The TMDL is presented for the 95th percentile daily *E. coli* load simulated under the TMDL scenario.

8.3.3. Spout Run

The Spout Run watershed encompasses the Page Brook watershed (sub-watersheds 1-6), the Roseville Run watershed (sub-watersheds 7-14), and sub-watersheds 15-20, which drain directly to Spout Run. To develop the bacteria TMDL for Spout Run, the upstream TMDLs developed for Page Brook and Roseville Run must be considered. The Spout Run TMDL included the upstream reductions called for in Page Brook and Roseville Run and determined the additional reductions (if any) needed in sub-watersheds 15-20 to meet bacteria water quality standards at the outlet of the Spout Run watershed (sub-watershed 20).

8.3.3.1. Allocation Scenarios

A variety of allocation scenarios were evaluated to meet the *E. coli* TMDL goal of a calendar-month geometric mean of 126 cfu/100mL and a violation rate of less than 10.5% for the instantaneous target of 235 cfu/100mL. Each scenario represents a different combination of bacteria load reductions from the various sources. These load reductions were modeled by decreasing the amount of bacteria applied to the land surface or directly deposited in the stream. In the model, this has the effect of reducing the amount of bacteria that reaches the stream, the ultimate goal of the TMDL. Thus, the reductions called for in the various scenarios indicate the need to decrease the amount of bacteria reaching the stream in order to meet the applicable water quality standard. The reductions are not intended to infer that agricultural producers should reduce their herd size or limit the use of manure as fertilizer or soil conditioner. Rather, it is

assumed that the required reductions from affected agricultural source categories (cattle direct deposit, cropland, etc.) will be accomplished by implementing BMPs like filter strips, stream fencing, and off-stream watering; and that required reductions from residential source categories will be accomplished by repairing aging septic systems, eliminating straight pipe discharges, and other appropriate measures included in the TMDL Implementation Plan.

Various allocation scenarios for the Spout Run watershed are summarized in Table 8-13. The first scenario represents the future condition described in Section 8.2. This scenario produces a 45% violation rate of the geometric mean standard and a 23% violation rate of the instantaneous target. The second scenario evaluates the results of eliminating anthropogenic sources of bacteria. This scenario demonstrates that the TMDL can be met without reductions in wildlife direct deposit or forest runoff. Scenario 3 shows the results of eliminating straight pipes, which makes only small improvements in *E. coli* violation rates. Because straight pipes are illegal and must be corrected if identified, all remaining scenarios contain 100% reductions in straight pipes, even though those reductions have small impacts on overall violation rates.

The next several scenarios (4-6) show the results of eliminating bacteria from cattle direct deposit, agricultural runoff, and residential runoff, respectively. Of these three, elimination of cattle direct deposits had the largest impact on violation rates. With just the elimination of cattle direct deposits throughout the watershed, Spout Run could meet the TMDL target. The elimination of other sources independently would not be enough to meet the TMDL. Scenario 7 shows the results of making modest reductions in each of these sources simultaneously. Once again, these reductions were not enough to meet the water quality standard. Scenarios continued to make reductions in these sources until the water quality standard was met. Scenario 8 shows that watershed-wide reductions of 67% in cattle direct deposits, agricultural runoff, and residential runoff (in combination with the elimination of straight pipes) would be necessary to meet the geometric mean standard and reduce violations of the instantaneous target to below 10.5%. Scenario 8 is an acceptable reduction scenario for the Spout Run TMDL, however, it does not ensure compliance with water quality standards in the upstream tributaries (Page Brook and Roseville Run). In order to meet water quality standards in these upstream watersheds, much larger bacteria reductions are required (see Section 8.3.1 and 8.3.2). Scenario 9 shows the results in Spout Run when upstream reductions are consistent with the TMDLs for Page Brook

and Roseville Run. This scenario shows that if upstream TMDLs were implemented, Spout Run would achieve water quality standards with only the elimination of straight pipes in sub-watersheds 15-20. No other reductions in sub-watershed 15-20 would be needed. Based on discussions with the Local Steering Committee, scenario 8 was selected as the TMDL scenario. This scenario provides equity among sources and it maintains reductions for the lower watershed. The Local Steering Committee felt that maintaining equity among sources and throughout the watershed was important.

Table 8-13. Bacteria Allocation Scenarios for Spout Run.

Scenario[1]	Fecal Coliform Loading Reductions (%)							% Violation of *E. coli* Standard		Average Annual *E. coli* Load (cfu/yr)
	Straight Pipes	Cattle DD	Wildlife DD	Permitted Point Sources	Agricultural Runoff	Residential/ Urban Runoff	Forest Runoff	Geometric Mean	Instantane-ous	
Future Condition	0%	0%	0%	0%	0%	0%	0%	45.00%	22.50%	3.93E+13
2	100%	100%	0%	0%	100%	100%	0%	0.00%	0.00%	1.24E+12
3	100%	0%	0%	0%	0%	0%	0%	41.67%	20.25%	3.72E+13
4	100%	100%	0%	0%	0%	0%	0%	0.00%	9.20%	2.84E+13
5	100%	0%	0%	0%	100%	0%	0%	33.33%	10.846%	1.47E+13
6	100%	0%	0%	0%	0%	100%	0%	30.00%	13.90%	3.33E+13
7	100%	50%	0%	0%	50%	50%	0%	10.00%	4.93%	2.01E+13
8	100%	67%	0%	0%	67%	67%	0%	0.00%	2.19%	1.41E+13
9 (Upstream TMDLs Implemented)	100%	0%	0%	0%	0%	0%	0%	0.00%	6.29%	2.12E+13

[1] Scenarios highlighted in yellow represent reduction levels that the geometric mean standard and meet a 10.5% violation rate of the instantaneous *E. coli* target. These represent acceptable scenarios for defining the TMDL.

Under the TMDL scenario, the average annual *E. coli* load in Spout Run is 1.41×10^{13} cfu/yr, which is a 64% reduction in the average annual *E. coli* load of 3.91×10^{13} under existing conditions. Figure 8-9 shows the resulting *E. coli* concentrations under the TMDL scenario. Monthly geometric means are below the water quality standard of 126 cfu/100mL for the entire simulation period. This demonstrates that the TMDL scenario is protective of the recreational designated use of Spout Run.
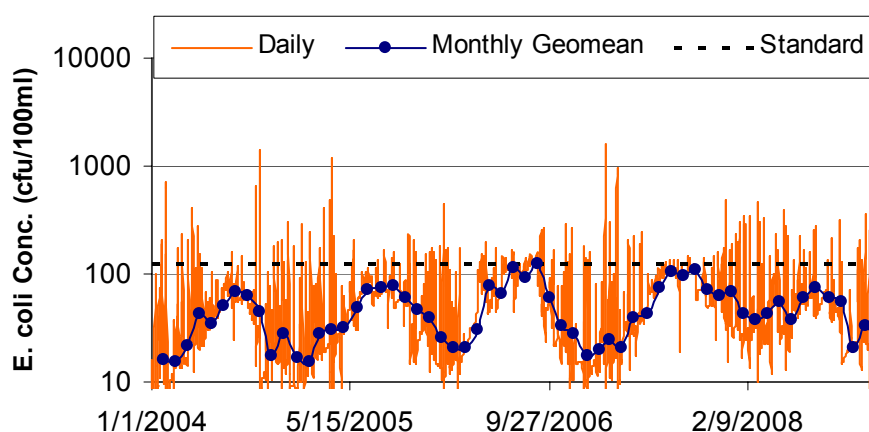
Figure 8-9. *E. coli* Concentrations in Spout Run Under Successful TMDL Conditions.

8.3.3.2. Wasteload Allocation

The wasteload allocation (or WLA) portion of a TMDL includes the contributions from permitted point sources in the watershed. Within the Spout Run watershed, the Boyce STP is currently the only point source permitted to discharge fecal bacteria. The Boyce STP is permitted to discharge up to 0.05 MGD of treated wastewater with an *E. coli* concentration of 126 cfu/100mL. In order to allow for future growth, an additional wasteload allocation was apportioned for the Spout Run watershed. DEQ guidance for bacteria TMDL development recommends adding a future growth wasteload allocation of 5 times the existing wasteload allocation. For Spout Run, this 5-times allocation was split evenly between the Page Brook and Roseville Run watersheds. Since the existing permitted flow of the Boyce STP is 0.05 MGD, a

future growth flow of 0.125 MGD (2.5 times the existing flow) was added to both the Page

Brook and Roseville Run watersheds, resulting in a future growth flow of 0.25 MGD for Spout

Run. For Spout Run, the existing wasteload plus the additional future growth resulted in an

annual *E. coli* wasteload allocation of 5.22 x 10^{11} cfu/yr and a daily *E. coli* wasteload allocation

of 1.43 x 10^9 cfu/d (Table 8-14).

Table 8-14. Wasteload Allocation Table for the Spout Run TMDL.

Facility	Permit #	Permitted Flow (MGD)	Permitted *E. coli* Conc. (cfu/100mL)	Annual *E. coli* WLA (cfu/yr)	Daily *E. coli* WLA (cfu/d)
Boyce STP	VA0085171	0.05	126	8.70E+10	2.38E+08
Future Growth	NA	0.25	126	4.35E+11	1.19E+09
Total		0.3	126	5.22E+11	1.43E+09

8.3.3.3. TMDL Expression

The TMDL for Spout Run was derived from allocation scenario 8 (Table 8-13). Under this

scenario, the TMDL was calculated as 1.41 x 10^{13} cfu/yr. Table 8-15 provides the TMDL

equation for Spout Run expressed on an average annual basis. This TMDL includes a WLA for

permitted point sources (including a future growth factor), a load allocation (LA) for non-point

sources, and an implicit margin of safety.

Table 8-15. Total Maximum Daily Load of *E. coli* for Spout Run Expressed as an Average Annual Load.

Stream	WLA (cfu/yr)	LA (cfu/yr)	MOS	TMDL (cfu/yr)
Spout Run	5.22E+11	1.36E+13	Implicit	1.41E+13

In order to comply with current USEPA guidance (USEPA, 2007), the Spout Run bacteria

TMDL was also expressed as a daily load by evaluating the variability and distribution of

simulated loads (Table 8-16). Because the LSPC model produces continuous simulation results

during the modeling period, the distribution of daily *E. coli* loads under the TMDL scenario

could be used to derive the daily expression of the TMDL. The 95th percentile daily *E. coli* load was selected to represent the daily TMDL expression.

Table 8-16. Total Maximum Daily Load of *E. coli* for Spout Run Expressed as a Daily Load.

Stream	WLA[1] (cfu/d)	LA (cfu/d)	MOS	TMDL[2] (cfu/d)
Spout Run	1.43E+09	1.11E+11	Implicit	1.12E+11

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

[2] The TMDL is presented for the 95th percentile daily E. coli load simulated under the TMDL scenario.

8.4. SEDIMENT TMDL

8.4.1. TMDL Endpoint

The sediment TMDL is being developed to address the aquatic life (benthic) impairment in Spout Run. The TMDL, therefore, must represent a sediment load that is protective of the aquatic life use. There are several options for developing this protective TMDL endpoint. One option is to develop the TMDL to meet a certain instream pollutant concentration. For suspended sediment, however, the Commonwealth of Virginia does not have established water quality standards. For this reason, the most commonly used approach for sediment is a reference watershed comparison. In this approach, a similar watershed with unimpaired benthic conditions is used to set a target sediment load that will support a healthy benthic community.

To determine the TMDL endpoint for Spout Run, VADEQ compared the sediment load duration curve for Spout Run with that of an unimpaired reference stream (Passage Creek) of the same order and within the same ecoregion. Measured flow and TSS concentrations from Passage Creek and Spout Run were used to develop sediment rating curves that relate the load of sediment in each stream as a function of flow (Figure 8-10). The regression equation from these sediment rating curves were used to produce sediment load duration curves for each stream based on the flow frequency of Spout Run (Figure 8-11). This figure shows that at all flow frequencies, Spout Run carries a higher load of sediment than a comparable reference. At an

average annual flow of 23 cfs, Spout Run carries approximately 0.46 T/d of sediment compared to only 0.21 T/d at equivalent flow in the reference stream. In order to reduce Spout Run sediment loads to levels equivalent to the reference stream, a 54% reduction would be needed at average annual flows.

This reduction level (54%) was used to set the TMDL target for Spout Run. A 54% reduction from the GWLF-estimated annual sediment load of 238 T/yr results in a TMDL target load of 109 T/yr. This value was set as the TMDL for Spout Run.
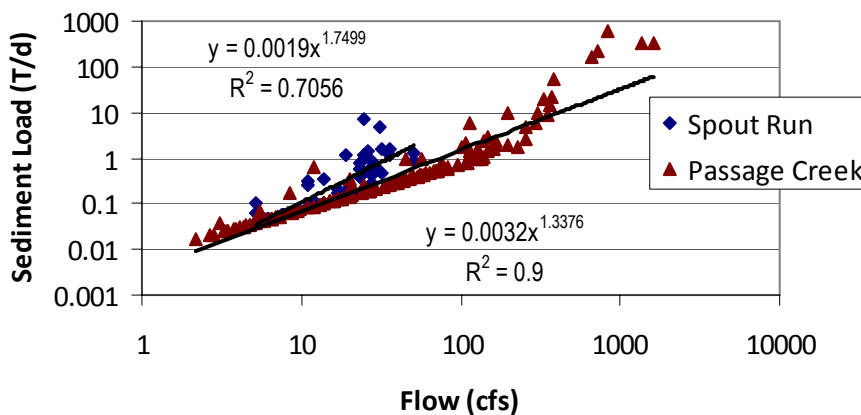
Figure 8-10. Sediment Rating Curves for Spout Run and Passage Creek.
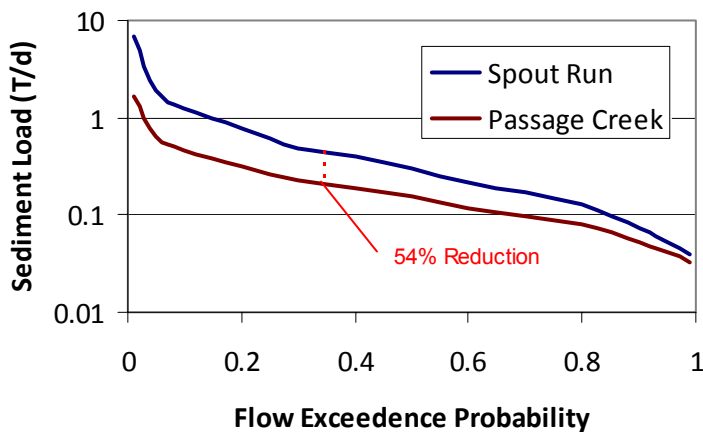
Figure 8-11. Sediment Load Duration Curves for Spout Run and Passage Creek.

8.4.2. Margin of Safety

A margin of safety (or MOS) of 5% was used in the Spout Run Sediment TMDL. The TMDL target was an average annual load of 109 tonnes/yr. Subtracting a 5% margin of safety of 5.47 tonnes/yr, the target for allocated loads under the TMDL scenario was 104 tonnes/yr.

8.4.3. Allocation Scenarios

TMDL allocations were based on GWLF sediment modeling results for 2004-2008. Reductions from various sediment sources were set to meet the annual TMDL of 109 tonnes/yr with a 5% margin of safety. The first two scenarios represent the existing conditions and future conditions for Spout Run. The future condition represented slightly higher sediment loads than the existing conditions based on changing land use and point source loads that were set to permit maximums. Scenario 3 included equivalent reductions of 54% from residential/urban areas, cropland, pasture, degraded riparian pasture, transitional areas, and stream bank erosion. These reductions were not sufficient to meet the TMDL when the 5% margin of safety was considered. Scenario 4 increased reductions to 60% in order to meet the TMDL target. This scenario represents a successful allocation that meets the TMDL target and provides an equitable distribution among sources.

In allocation scenarios 5-9, reduction levels were increased for the largest sediment sources and decreased for less significant sources. In order to meet the TMDL with only reductions from the largest sediment source (stream bank erosion), a 100% reduction would be needed (Scenario 6). A 74% reduction would be needed from stream bank erosion and degraded riparian pasture if reductions from only those two sources were considered (Scenario 7). Scenario 8 represents a 70% reduction from stream bank erosion and a 45% reduction from residential/urban areas, cropland, pasture, degraded riparian pasture, and transitional areas. Scenario 9 represents a 67% reduction from stream bank erosion and degraded riparian pasture and a 30% reduction from residential/urban areas, cropland, pasture, and transitional areas. Scenarios 6-9 all meet the TMDL target and would be acceptable TMDL allocations, but Scenario 9 was selected for the TMDL since it represents larger reductions for the larger sources and reasonable reductions for smaller sources. The remaining successful scenarios (4, 6, 7, and 8) could also be acceptable

choices during implementation planning if the implementation planning team determined that any of these scenarios would be preferable.

Table 8-17. Sediment Allocation Scenarios for Spout Run.

Scenario[1]	Sediment Loading Reductions (%)								Average Annual Sediment Load (tonnes/yr)
	Residential /Urban Runoff	Cropland Runoff	Pasture Runoff	Degraded Riparian Pasture Runoff	Forest Runoff	Transitional Runoff	Point Sources	Stream Bank Erosion	
Existing Condition	0%	0%	0%	0%	0%	0%	0%	0%	238
Future Condition	0%	0%	0%	0%	0%	0%	0%	0%	245
3	54%	54%	54%	54%	0%	54%	0%	54%	124
4	60%	60%	60%	60%	0%	60%	0%	60%	109
5	0%	0%	0%	0%	0%	0%	0%	75%	145
6	0%	0%	0%	0%	0%	0%	0%	100%	109
7	0%	0%	0%	74%	0%	0%	0%	74%	108
8	45%	45%	45%	45%	0%	45%	0%	70%	109
9	30%	30%	30%	67%	0%	30%	0%	67%	109

[1] Scenarios highlighted in yellow represent reasonable reduction levels that meet the TMDL criteria. Scenario 9 was selected as the TMDL scenario. Scenarios 4, 6, 7 and 8 represent other reasonable alternatives that could be implemented to achieve the TMDL.

The TMDL scenario (scenario 9) for Spout Run is presented in Table 8-18. Under this scenario, an annual average of 109 tonnes of sediment per year is discharged from the Spout Run watershed. Even though stream bank erosion is reduced by 67% under this scenario, bank erosion still contributes nearly half (43%) of the annual sediment load.

Table 8-18. Sediment Loads in Spout Run Under TMDL Allocation.

Source	Future Sediment Load (T/yr)	% Reduction	TMDL Load (T/yr)
Res/Urban	2.06	30%	1.44
Crop	8.14	30%	5.70
Pasture	26.9	30%	18.8
Degraded Riparian Pasture	51.1	67%	16.8
Forest	2.73	0%	2.73
Transitional	5.54	30%	3.88
Point Sources	7.44	0%	7.44
Bank erosion	141	67%	46.5
MOS (5%)			5.47
Total	245		109

8.4.4. Wasteload Allocation

The wasteload allocation (or WLA) portion of the TMDL includes sediment (in the form of TSS) contributions from 2 VPDES individual permits and 4 general construction stormwater permits in the Spout Run watershed. Section 6.1 describes the calculation of WLAs for these facilities. In general, wasteload allocations were determined based on permitted design flows and TSS concentrations. No reductions in sediment loadings from permitted point sources are called for under the TMDL scenario. Table 8-19 presents the wasteload allocations for permitted point sources in the Spout Run watershed on both an annual and a daily basis. The total WLA for Spout Run is 7.44 tonnes/yr on an annual basis and 0.0253 tonnes/d on a daily basis.

Table 8-19. Wasteload Allocation Table for the Spout Run Sediment TMDL.

Facility	Permit #	Permitted Flow (MGD)	Permitted Avg. TSS Conc. (mg/L)	Permitted Maximum TSS Conc. (mg/L)	Annual WLA (tonnes/yr)	Daily WLA (tonnes/d)
Boyce STP	VA0085171	0.05	30	45	2.07	0.00852
Prospect Hill Springs WTP	VA0090883	0.0181	30	60	0.750	0.00411
Construction Stormwater Permits					4.61	0.0126
				Total	7.44	0.0253

8.4.5. TMDL Expressions

The sediment TMDL in Spout Run is designed to restore aquatic life uses by reducing sedimentation and improving benthic habitat. While sediment loadings are very dynamic, the accumulation of sediment in the stream is reflective of conditions over extended time periods, ranging from seasonal to annual. Consequently, the most relevant expression of sediment loadings in the Spout Run TMDL is the annual average loading. Table 8-20 shows the wasteload allocation, the load allocation, the margin of safety, and total load for Spout Run expressed as an average annual load. No sediment reductions to the point sources are required. The recommended allocations for nonpoint sources call for 30% reductions from cropland, pasture, residential/urban, and transitional sources; and 67% reductions from degraded riparian pasture and stream bank erosion. Overall, the sediment load in Spout Run must be reduced by 54% in order to meet the established TMDL endpoint.

Table 8-20. Total Maximum Daily Load of Sediment for Spout Run Expressed as an Average Annual Load.

WLA (tonnes/yr)	LA (tonnes/yr)	MOS (tonnes/yr)	TMDL (tonnes/yr)
7.44	95.9	5.47	109

In order to comply with current USEPA guidance (USEPA, 2007), the Spout Run sediment TMDL was also expressed as a daily load by evaluating the variability and distribution of

simulated loads. The following formula from USEPA's *Technical Support Document for Water Quality-Based Toxics Control* (USEPA, 1991) and USEPA's draft *Options for Expressing Daily Loads in TMDLs* (USEPA, 2007) was used to calculate the daily expression of the TMDL:

$$MDL = LTA * \exp(Z_p\sigma_y - 0.5\sigma_y^2) \qquad [8.2]$$

Where,

> MDL = Maximum daily load,
>
> LTA = Long term average, which in this case is the average daily load calculated as the average annual load divided by 365,
>
> Z_p = p^{th} percentage point of the standard normal distribution (95th percentile was used),
>
> $\sigma_y = \sqrt{\ln(CV^2 + 1)}$, and
>
> CV = Coefficient of variation (estimated at 0.6).

The total maximum daily load was determined from Equation 8.2 using a 95th percentile, a CV of 0.6, and a long term average of 0.298. It should be noted that the maximum daily load expression represents extreme conditions (with a 5% frequency of occurrence), and routine loadings of this level would not meet average annual loadings that are necessary to restore aquatic life health.

Table 8-21. Total Maximum Daily Load of Sediment for Spout Run Expressed as a Daily Load.

WLA (tonnes/d)	LA (tonnes/d)	MOS (tonnes/d)	TMDL (tonnes/d)
0.0253	0.579	0.0318	0.636

CHAPTER 9: TMDL IMPLEMENTATION AND REASONABLE ASSURANCE

Once a TMDL has been approved by USEPA, measures must be taken to reduce pollution levels from both point and nonpoint sources. The following sections outline the framework used in Virginia to provide reasonable assurance that the required pollutant reductions can be achieved.

9.1. CONTINUING PLANNING PROCESS AND WATER QUALITY MANAGEMENT PLANNING

As part of the Continuing Planning Process, VADEQ staff will present both USEPA-approved TMDLs and TMDL implementation plans to the State Water Control Board (SWCB) for inclusion in the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e) and Virginia's Public Participation Guidelines for Water Quality Management Planning.

VADEQ staff will also request that the SWCB adopt TMDL WLAs as part of the Water Quality Management Planning Regulation (9VAC 25-720), except in those cases when permit limitations are equivalent to numeric criteria contained in the Virginia Water Quality Standards, such as in the case for bacteria. This regulatory action is in accordance with §2.2-4006A.4.c and §2.2-4006B of the Code of Virginia.

> **Frequently Asked Question:**
>
> *What happens after the TMDL Study is complete?*
> The TMDL will be submitted to EPA for approval. The next step is then to develop a TMDL Implementation Plan. This plan lays out the actions and costs necessary to implement the pollutant reductions called for in the TMDL.

SWCB actions relating to water quality management planning are described in VADEQ's public participation guidelines (VADEQ, 2004c), which can be found on VADEQ's web site at: http://www.deq.state.va.us/tmdl/pdf/ppp.pdf.

9.2. STAGED IMPLEMENTATION

In general, Virginia intends for the required control actions, including Best Management Practices (BMPs), to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. The iterative implementation of pollution control actions in the watershed has several benefits:

1. It enables tracking of water quality improvements following implementation through follow-up stream monitoring;

2. It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling;

3. It provides a mechanism for developing public support through periodic updates on implementation levels and water quality improvements;

4. It helps ensure that the most cost effective practices are implemented first; and

5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

9.3. IMPLEMENTATION OF WASTE LOAD ALLOCATIONS

Federal regulations require that all new or revised National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the assumptions and requirements of any applicable TMDL WLA (40 CFR §122.44 (d)(1)(vii)(B)). All such permits should be submitted to USEPA for review.

For the implementation of the WLA component of the TMDL, the Commonwealth utilizes the Virginia NPDES program. Requirements of the permit process should not be duplicated in the TMDL process, and permitted sources are not usually addressed through the development of any TMDL implementation plans.

9.3.1. Stormwater

VADEQ and VADCR coordinate separate state permitting programs that regulate the management of pollutants carried by stormwater runoff. VADEQ regulates stormwater discharges associated with industrial activities through its VPDES program, while VADCR regulates stormwater discharges from construction sites, and from municipal separate storm sewer systems (MS4s) through the VSMP program. Stormwater discharges from coal mining operations are permitted through NPDES permits by the Department of Mines, Minerals and Energy (DMME). As with non-stormwater permits, all new or revised stormwater permits must be consistent with the assumptions and requirements of any applicable TMDL WLA. If a WLA is based on conditions specified in existing permits, and the permit conditions are being met, no additional actions may be needed. If a WLA is based on reduced pollutant loads, additional pollutant control actions will need to be implemented.

9.3.2. TMDL Modifications for New or Expanding Dischargers

Permits issued for facilities with wasteload allocations developed as part of a TMDL must be consistent with the assumptions and requirements of these wasteload allocations (WLA), as per USEPA regulations. In cases where a proposed permit modification is affected by a TMDL WLA, permit and TMDL staff must coordinate to ensure that new or expanding discharges meet this requirement. In 2005, VADEQ issued guidance memorandum 05-2011 describing the available options and the process that should be followed under those circumstances, including public participation, USEPA approval, State Water Control Board actions, and coordination between permit and TMDL staff (VADEQ, 2005). The guidance memorandum is available on VADEQ's web site at http://www.deq.virginia.gov/waterguidance/.

9.4. IMPLEMENTATION OF LOAD ALLOCATIONS

The TMDL program does not impart new implementation authorities. Therefore, the Commonwealth intends to use existing programs to the fullest extent in order to attain its water quality goals. The measures for nonpoint source reductions, which can include the use of better treatment technology and the installation of best management practices (BMPs), are

implemented in an iterative process that is described along with specific BMPs in the TMDL implementation plan.

9.4.1. Implementation Plan Development

For the implementation of the TMDL's LA component, a TMDL implementation plan will be developed that addresses at a minimum the requirements specified in the Code of Virginia, Section 62.1-44.19.7. State law directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters". The implementation plan "shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments". USEPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process" (USEPA, 1999). The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

In order to qualify for other funding sources, such as USEPA's Section 319 grants, additional plan requirements may need to be met. The detailed process for developing an implementation plan has been described in the "TMDL Implementation Plan Guidance Manual", published in July 2003 (VADCR, 2003) and available upon request from the VADEQ and VADCR TMDL project staff or at http://www.deq.virginia.gov/tmdl/implans/ipguide.pdf

Watershed stakeholders will have opportunities to provide input and to participate in the development of the TMDL implementation plan. Regional and local offices of VADEQ, VADCR, and other cooperating agencies are technical resources to assist in this endeavor.

With successful completion of implementation plans, local stakeholders will have a blueprint to restore impaired waters and enhance the value of their land and water resources. Additionally, development of an approved implementation plan may enhance opportunities for obtaining financial and technical assistance during implementation.

9.4.2. Staged Implementation Scenarios

The purpose of the staged implementation scenarios is to identify one or more combinations of implementation actions that result in the reduction of controllable sources to the maximum extent practicable using cost-effective, reasonable BMPs for nonpoint source control. Among the most efficient sediment BMPs for both urban and rural watersheds are infiltration and retention basins, riparian buffer zones, grassed waterways, streambank protection and stabilization, and wetland development or enhancement.

Actions identified during TMDL implementation plan development that go beyond what can be considered cost-effective and reasonable will only be included as implementation actions if there are reasonable grounds for assuming that these actions will in fact be implemented.

If water quality standards are not met upon implementation of all cost-effective and reasonable BMPs, a Use Attainability Analysis may need to be initiated since Virginia's water quality standards allow for changes to use designations if existing water quality standards cannot be attained by implementing effluent limits required under §301b and §306 of Clean Water Act, and cost effective and reasonable BMPs for nonpoint source control. Additional information on UAAs is presented in Section 9.6, Attainability of Designated Uses.

9.4.3. Link to Ongoing Restoration Efforts

Implementation of this TMDL will contribute to on-going water quality improvement efforts aimed at restoring water quality in the Chesapeake Bay. In 2005, the Secretary of Natural Resources developed tributary strategies for the major basins discharging to the Chesapeake Bay (VASNR, 2005). These strategies set nutrient and sediment reductions for the basins and highlight practices to achieve those reductions. Many of the BMPs that will be used to reduce bacteria in Spout Run will also be effective in reducing nutrients and sediment contributions as part of the Potomac River Basin Tributary Strategy. For example, livestock fencing and riparian buffers will be essential components of the Spout Run Implementation Plan. These same BMPs are elements of the Potomac Tributary Strategy to reduce nutrient and sediment inputs to the Chesapeake Bay. More information on the Potomac Basin Tributary Strategy can be found at:

http://www.naturalresources.virginia.gov/Initiatives/WaterQuality/FinalizedTribStrats/shenandoah.pdf.

9.4.4. Implementation Funding Sources

The implementation of pollutant reductions from non-regulated nonpoint sources relies heavily on incentive-based programs. Therefore, the identification of funding sources for non-regulated implementation activities is a key to success. Cooperating agencies, organizations and stakeholders must identify potential funding sources available for implementation during the development of the implementation plan in accordance with the "Virginia Guidance Manual for Total Maximum Daily Load Implementation Plans" (VADCR, 2003). The TMDL Implementation Plan Guidance Manual contains information on a variety of funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

Some of the major potential sources of funding for non-regulated implementation actions may include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, USEPA Section 319 funds, the Virginia State Revolving Loan Program (also available for permitted activities), Virginia Agricultural Best Management Practices Cost-Share Programs, the Virginia Water Quality Improvement Fund (available for both point and nonpoint source pollution), tax credits and landowner contributions.

With additional appropriations for the Water Quality Improvement Fund in recent years, the Fund has become a significant funding stream for agricultural BMPs and wastewater treatment plants. Additionally, funding is being made available to address urban and residential water quality problems. Information on WQIF projects and allocations can be found at http://www.deq.virginia.gov/bay/wqif.html and at

http://www.dcr.virginia.gov/soil_&_water/wqia.shtml.

9.5. FOLLOW-UP MONITORING

Following the development of the TMDL, VADEQ will make every effort to continue to monitor the impaired stream in accordance with its ambient and biological monitoring programs.

VADEQ's Ambient Watershed Monitoring Plan for conventional pollutants calls for watershed monitoring to take place on a rotating basis, bi-monthly for two consecutive years of a six-year cycle. In accordance with VADEQ Guidance Memo No. 03-2004 (VADEQ, 2004d), during periods of reduced resources, monitoring can temporarily discontinue until the TMDL staff determines that implementation measures to address the source(s) of impairments are being installed. Monitoring can resume at the start of the following fiscal year, next scheduled monitoring station rotation, or where deemed necessary by the regional office or TMDL staff, as a new special study. Since there may be a lag time of one-to-several years before any improvement in the benthic community will be evident, follow-up biological monitoring may not have to occur in the fiscal year immediately following the implementation of control measures.

The purpose, location, parameters, frequency, and duration of the monitoring will be determined by the VADEQ staff, in cooperation with VADCR staff, the Implementation Plan Steering Committee and local stakeholders. Whenever possible, the location of the follow-up monitoring station(s) will be the same as the listing station. At a minimum, the monitoring station must be representative of the original impaired segment. The details of the follow-up monitoring will be outlined in the Annual Water Monitoring Plan prepared by each VADEQ Regional Office. Other agency personnel, watershed stakeholders, etc. may provide input on the Annual Water Monitoring Plan. These recommendations must be made to the VADEQ regional TMDL coordinator by September 30 of each year.

VADEQ will continue to monitor bacteria and aquatic life health in Spout Run at station 1BSPR000.40 according to its ambient and benthic monitoring programs. When an Implementation Plan is developed for Spout Run and implementation of that plan begins, VADEQ will increase the frequency of monitoring at this site to assess water quality progress as BMPs are implemented.

VADEQ staff, in cooperation with VADCR staff, the Implementation Plan Steering Committee and local stakeholders, will continue to use data from the ambient monitoring stations to evaluate reductions in pollutants ("water quality milestones" as established in the IP), the effectiveness of the TMDL in attaining and maintaining water quality standards, and the success of implementation efforts. Recommendations may then be made, when necessary, to target

implementation efforts in specific areas and continue or discontinue monitoring at follow-up stations.

In some cases, watersheds will require monitoring above and beyond what is included in VADEQ's standard monitoring plan. Ancillary monitoring by citizens' or watershed groups, local government, or universities is an option that may be used in such cases. An effort should be made to ensure that ancillary monitoring follows established QA/QC guidelines in order to maximize compatibility with VADEQ monitoring data. In instances where citizens' monitoring data is not available and additional monitoring is needed to assess the effectiveness of targeting efforts, TMDL staff may request of the monitoring managers in each regional office an increase in the number of stations or monitor existing stations at a higher frequency in the watershed. The additional monitoring beyond the original bimonthly single station monitoring will be contingent on staff resources and available laboratory budget. More information on citizen monitoring in Virginia and QA/QC guidelines is available at http://www.deq.virginia.gov/cmonitor/.

To demonstrate that the watershed is meeting water quality standards in watersheds where corrective actions have taken place (whether or not a TMDL or Implementation plan has been completed), VADEQ must meet the minimum data requirements from the original listing station or a station representative of the originally listed segment. The minimum data requirement for conventional pollutants (bacteria, dissolved oxygen, etc) is bimonthly monitoring for two consecutive years. For biological monitoring, the minimum requirement is two consecutive samples (one in the spring and one in the fall) in a one year period.

9.6. ATTAINABILITY OF DESIGNATED USES

In some streams for which TMDLs have been developed, factors may prevent the stream from attaining its designated use.

In order for a stream to be assigned a new designated use, or a subcategory of a use, the current designated use must be removed. To remove a designated use, the state must demonstrate that the use is not an existing use, and that downstream uses are protected. Such uses will be attained by implementing effluent limits required under §301b and §306 of Clean Water Act and by

implementing cost-effective and reasonable best management practices for nonpoint source control (9 VAC 25-260-10 paragraph I).

The state must also demonstrate that attaining the designated use is not feasible because:

1. Naturally occurring pollutant concentration prevents the attainment of the use;

2. Natural, ephemeral, intermittent or low flow conditions prevent the attainment of the use unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating state water conservation;

3. Human-caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place;

4. Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the waterbody to its original condition or to operate the modification in such a way that would result in the attainment of the use;

5. Physical conditions related to natural features of the water body, such as the lack of proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life use protection; or

6. Controls more stringent than those required by §301b and §306 of the Clean Water Act would result in substantial and widespread economic and social impact.

This and other information is collected through a special study called a UAA. All site-specific criteria or designated use changes must be adopted by the SWCB as amendments to the water quality standards regulations. During the regulatory process, watershed stakeholders and other interested citizens, as well as the USEPA, will be able to provide comment during this process. Additional information can be obtained at http://www.deq.virginia.gov/wqs/.

The process to address potentially unattainable reductions based on the above is as follows: As a first step, measures targeted at the controllable, anthropogenic sources identified in the TMDL's staged implementation scenarios will be implemented. The expectation would be for the

reductions of all controllable sources to the maximum extent practicable using the implementation approaches described above. VADEQ will continue to monitor biological health and water quality in the stream during and subsequent to the implementation of these measures to determine if water quality standards are attained. This effort will also help to evaluate if the modeling assumptions were correct. In the best-case scenario, water quality goals will be met and the stream's uses fully restored using effluent controls and BMPs. If, however, water quality standards are not being met, and no additional effluent controls and BMPs can be identified, a UAA would then be initiated with the goal of re-designating the stream for a more appropriate use or subcategory of a use.

A 2006 amendment to the Code of Virginia under 62.1-44.19:7E provides an opportunity for aggrieved parties in the TMDL process to present to the State Water Control Board reasonable grounds indicating that the attainment of the designated use for a water is not feasible. The Board may then allow the aggrieved party to conduct a use attainability analysis according to the criteria listed above and a schedule established by the Board. The amendment further states that "If applicable, the schedule shall also address whether TMDL development or implementation for the water shall be delayed."

CHAPTER 10: PUBLIC PARTICIPATION

Public participation was elicited at every stage of the TMDL development in order to receive input from stakeholders and to apprise the stakeholders of the progress made. Public participation was encouraged through holding public meetings in the watershed and by forming a Spout Run TMDL Local Steering Committee. The Local Steering Committee was a group of local citizens, landowners, organizations, and government entities that could provide local input and assistance to VADEQ during the TMDL Study. The goal of the Local Steering Committee was to make sure that the technical aspects of the study (including model inputs and assumptions) were accurate as well as acceptable to the community.

On March 24, 2009, VADEQ held a public meeting at the Boyce Fire Hall to explain the Spout Run impairments to local citizens and describe the TMDL Study that would take place. The meeting was advertised through signs throughout the watershed, e-mail announcements to local contacts, letters to VPDES permit holders, notice publication in the Virginia Register, announcement through the Lord Fairfax Soil and Water Conservation District, and notification through local media outlets. Approximately 36 people attended the meeting. At the meeting, VADEQ explained the bacterial and aquatic life impairments in Spout Run, described the TMDL process, and provided an open invitation to participate on the Local Steering Committee. Handouts of the presentation were made available to attendees of the meeting and were distributed electronically upon request to those that were not able to attend the meeting.

The Local Steering Committee met on February 3, 2009, March 31, 2009, and again on January 14, 2010. At the first meeting, the committee reviewed information on the overall impairments, and preliminary watershed characterization data. At the second meeting, the committee reviewed bacteria source information and stressor analysis results. Comments from the meeting were used to refine estimates of animal populations and bacteria source input data. In the third meeting, the committee reviewed bacteria and sediment modeling results and provided comment on the selection of TMDL allocation scenarios.

On February 24, 2010, a second public meeting was held in the Spout Run watershed. This meeting was once again advertised through fliers posted throughout the watershed, e-mail announcements, notice publication in the Virginia Register, and through personal contacts of the Local Steering Committee members. Approximately 20 people attended this final public meeting. At the meeting, VADEQ presented the draft TMDL report to the public and explained its development and conclusions. Handouts of the presentation and the executive summary of the draft report were made available to the public at the meeting. The full report was made available on the VADEQ website at:

http://gisweb.deq.virginia.gov/tmdlapp/tmdl_draft_reports.cfm. Following the meeting, a 30-day public comment period on the draft was initiated until March 29, 2010 (11.59pm). No comments were received on the draft during the comment period.

CHAPTER 11: REFERENCES

AVMA. 2007. *U.S. Pet Ownership and Demographics Sourcebook: 2007 Edition*. American Veterinary Medical Association, Schaumburg, IL. http://www.avma.org/reference/marketstats/ownership.asp

ASAE Standards, 45th edition. 1998. D384.1 DEC93. *Manure Production and Characteristics*. American Society of Agricultural Engineers, St. Joseph, Mich.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish*, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Census Bureau. 2000. U.S. Census Bureau , Washington, D.C. http://www.census.gov

Clarke County. 2007. *Clarke County Comprehensive Plan*. Clarke County, Berryville, VA. http://www.clarkecounty.gov/government/planning/comprehensive_plan.html.

Dai, T., R.L. Wetzel, Tyler, R.L. Christensen, and E.A. Lewis. 2000. *BasinSim 1.0 A Windows-Based Watershed Modeling Package User's Guide SRAMSOE #362*. (Computer program manual). Virginia Institute of Marine Science, School of Marine Science, College of William & Mary, Gloucester Point, VA. Available at http://www.vims.edu/bio/vimsida/basinsim.html.

Duda, P., J. Kittle, Jr., M. Gray, P. Hummel, and R. Dusenbury. 2001. *WinHSPF, Version 2.0, An Interactive Windows Interface to HSPF, User Manual*. Contract No. 68-C-98-010. U.S. Environmental Protection Agency, Washington, D.C. pp. 95.

Evans, B.M., S.A. Sheeder, and D.W. Lehning. 2003. A spatial technique for estimating streambank erosion based on watershed characteristics. *Journal of Spatial Hydrology*. 3(1):1-13.

Graves, A.K., C. Hagedorn, A. Teetor, M. Mahal, A.M. Booth, and R.B. Reneau. 2002. Antibiotic resistance profiles to determine sources of fecal contamination in a rural Virginia watershed. *Journal of Environmental Quality*. 31: 1300-1308.

Hagedorn, C., S.L. Robinson, J.R. Filtz, S.M. Grubbs, T.A. Angier, and R.B. Reneau. 1999. Determining sources of fecal pollution in a rural Virginia watershed with antibiotic resistance patterns in fecal streptococci. *Applied and Environmental Microbiology*. 65(12):5522-5531.

Haith, D.A., Mandel, R., and R.S. Wu. 1992. *GWLF: Generalized Watershed Loading Functions (User's Manual, Version 2.0)*. Cornell University, Ithica, NY.

Hamon, R.W. 1961. Estimating Potential Evapotranspiration. *Proceedings of the American Society of Civil Engineers, Journal of the Hydraulic Division*. Vol. 87, No. HY3, p 107-120.

Jones, R.C. and R. Hansen. 2002a. *Bioassessment of Spout Run: Clarke Co., Virginia.* Submitted to Office of Planning, County of Clarke, Berryville, VA.

Jones, R.C., L. Astin, and K. Rowland. 2002b. *Bioassessment of Page Brook: Final Report.* Submitted to Office of Planning, County of Clarke, Berryville, VA.

Jones, R.C., L. Astin, and K. Rowland. 2002c. *Bioassessment of Roseville Run Watershed: Clarke Co., Virginia*. Submitted to Office of Planning, County of Clarke, Berryville, VA.

Kaufmann, P.R., P. Levine, E.G. Robinson, C. Seeliger, and D. Peck. 1999. *Quantifying Physical Habitat in Wadeable Streams*. EPA/620/R-99/003. U.S. Environmental Protection Agency, Washington, D.C.

Lumb, A.M., McCammon, R.B., and J.L. Kittle, Jr. 1994. *Users Manual for an Expert System (HSPEXP) for Calibration of the Hydrologic Simulation Program--Fortran: U.S. Geological Survey Water-Resources Investigations Report 94-4168*. U.S. Geological Survey, Washington, DC.

MapTech, Inc. 2008. *Bacterial Source Tracking Analyses to Support Virginia's TMDLs*. MapTech, Inc., Blacksburg, VA.

Mara, D.D. and J.I. Oragui. 1981. Occurrence of Rodococcus coprophilus and associated actinomycetes in feces, sewage, and freshwater. *Applied and Environmental Microbiology*. 42(6):1037-1042.

Metcalf and Eddy. 1991. *Wastewater Engineering: Treatment, Disposal, and Reuse (III ed.)*. McGraw-Hill, New York.

McShea, W.J., C.M. Stewart, L.J. Kearns, S. Liccioli, and D. Kocka. 2007. *Factors Affecting Autumn Deer/Vehicle Collisions in a Rural County in Virginia*. National Zoological Park, Front Royal, Virginia.

NCDC. 2009. National Climatic Data Center, U.S. Department of Commerce. http://lwf.ncdc.noaa.gov/oa/climate/stationlocator.html

NRCS. 2006. *U.S. General Soil Map (STATSGO) for Virginia*. Soil Survey Staff, Natural Resources Conservation Service, U.S. Department of Agriculture, Washington, DC. http://soildatamart.nrcs.usda.gov

Pond, G.J. 2004. *Effects of Surface Mining and Residential Land Use on Headwater Stream Biotic Integrity*. Kentucky Department of Environmental Protection Division of Water. July, 2004. p.33.

Schueler, T.R. 1987. *Controlling Urban Runoff: A Practical Manual for Planning and Design of Urban BMPs*. Metropolitan Washington Council of Governments, Washington, D.C.

SERCC. 2006. Southeast Regional Climate Center, 1000 Assembly St., Suite 230, Columbia, SC 29201. http://www.sercc.com/

State Water Control Board. 2006. 9VAC 25-260. *Virginia Water Quality Standards, January, 2006*. State Water Control Board, Richmond, Virginia. http://www.deq.virginia.gov/wqs/documents/WQS06_EDIT_001.pdf

Tetra Tech. 2003. *A Stream Condition Index for Virginia Non-Coastal Streams*. Tetra Tech, Inc., Owings Mills, MD. http://www.deq.state.va.us/watermonitoring/pdf/vastrmcon.pdf.

Tetra Tech. 2005. *Loading Simulation Program C++ Model Version 4.01*. Tetra Tech, Inc., Fairfax, Virginia.

USDA. 2003. *Revised Universal Soil Loss Equation Version 2 (RUSLE 2) Users Guide*. U.S. Department of Agriculture, Agricultural Research Service, Washington, DC. http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm

USDA-NASS. 2007. *Census of Agriculture. Volume 1, Chapter 2: Virginia County Level Data.* U. S. Department of Agriculture, National Agricultural Statistics Service, Washington, D.C. http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_County_Level/Virginia/index.asp

USDA-NASS. 2008. *2008 Virginia Agriculture Statistics and Resource Directory*. U. S. Department of Agriculture, National Agricultural Statistics Service, Virginia Field Office, Richmond, VA. http://www.nass.usda.gov/QuickStats/

USEPA. 1986. *Ambient Water Quality Criteria for Bacteria – 1986*. EPA 440/5-84-002. U.S. Environmental Protection Agency, Office of Water, Regulations and Standards Criteria and Standards Division, Washington, DC.

USEPA. 1991. *Technical Support Document for Water Quality-Based Toxics Control*. EPA 505/2-90-001. U.S. Environmental Protection Agency, Office of Water Enforcement and Permits, Office of Water Regulations and Standards, Washington, DC.

USEPA. 1999. *Draft Guidance for Water Quality-based Decisions: The TMDL Process (Second Edition)*. EPA 841-D-99-001. U.S. Environmental Protection Agency, Office of Water, Washington, D.C. http://www.epa.gov/owow/tmdl/propguid/Guidance.htm

USEPA. 2000. *Stressor Identification Guidance Document*. EPA-822-B-00-025. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, DC.

USEPA. 2007. *Options for Expressing Daily Loads in TMDLs*. Draft, June 22, 2007. U.S. Environmental Protection Agency, Office of Wetlands, Oceans & Watersheds, Washington, DC.

USGS. 2001. National Land Cover Dataset. U.S. Geological Survey, Sioux Falls, SD. http://www.mrlc.gov/nlcd_multizone_map.php

VADCR. 2002. *Modeling Cattle Access*. Virginia Tech Biological Systems Engineering and Maptech, Blacksburg, VA.

VADCR. 2003. *Guidance Manual for Total Maximum Daily Load Implementation Plans*. The Commonwealth of Virginia: Department of Conservation and Recreation and Department of Environmental Quality, Richmond, Virginia. http://www.deq.virginia.gov/tmdl/implans/ipguide.pdf

VADEQ. 1998. *1998 305(b) Water Quality Assessment Report*. Virginia Department of Environmental Quality, Richmond, Virginia.

VADEQ. 2003. *Guidance Memo No. 03-2012: HSPF Model Calibration and Verification for Bacteria TMDLs.* Virginia Department of Environmental Quality, Richmond, Virginia.

VADEQ. 2004. *Final 2004 305(b)/303(d) Water Quality Assessment Integrated Report*. Virginia Department of Environmental Quality, Richmond, Virginia. http://www.deq.virginia.gov/wqa/ir2004.html

VADEQ. 2004b. *Bacteria TMDLs for Abrams Creek and Upper and Lower Opequon Creek Located in Frederick and Clarke County, Virginia*. Virginia Department of Environmental Quality, Richmond, Virginia. http://www.deq.virginia.gov/tmdl/apptmdls/shenrvr/abropefc.pdf

VADEQ. 2004c. *Public Participation Procedures for Water Quality Management Planning*. Virginia Department of Environmental Quality, Richmond, Virginia. http://www.deq.state.va.us/tmdl/pdf/ppp.pdf

VADEQ. 2004d. *Guidance Memo No. 03-2004: Managing Water Monitoring Programs While Under Reduced Resources*. Larry Lawson, Virginia Department of Environmental Quality, Richmond, Virginia. http://www.deq.virginia.gov/waterguidance/pdf/032004.pdf

VADEQ. 2005. *Guidance Memo 05-2011: TMDL Modifications in Response to New or Expanding Discharges*. Ellen Gilinsky, Virginia Department of Environmental Quality, Richmond, Virginia. http://www.deq.virginia.gov/waterguidance/pdf/052011.pdf

VADEQ. 2006. *Using Probabilistic Monitoring Data to Validate the Non-Coastal Virginia Stream Condition Index*. VDEQ Technical Bulletin WQA/2006-001. Virginia Department of Environmental Quality, Richmond, Virginia. http://www.deq.virginia.gov/probmon/pdf/scival.pdf

VADEQ. 2007. *Water Quality Assessment Guidance Manual for Y2008 305(b)/303(d) Integrated Water Quality Report*. Virginia Department of Environmental Quality, Richmond, Virginia. http://www.deq.virginia.gov/wqa/pdf/2008ir/2008_WQA_Guidance-Final.pdf

VADEQ. 2007b. *Total Maximum Daily Load Development for the James River Basin*. Virginia Department of Environmental Quality, Richmond, Virginia. http://www.deq.virginia.gov/tmdl/apptmdls/jamesrvr/jmslate.pdf

VADEQ. 2008. *Final 2008 305(b)/303(d) Water Quality Assessment Integrated Report*. Virginia Department of Environmental Quality, Richmond, Virginia. http://www.deq.virginia.gov/wqa/ir2008.html

VADOF. 2005. *Virginia Forest Cover Map 2005: Level 2 Classification*. Virginia Department of Forestry, Charlottesville, VA. http://www.dof.virginia.gov/gis/dwnld-2005-for-cov-II-faq.shtml

VASNR. 2005. *Commonwealth of Virginia Chesapeake Bay Nutrient and Sediment Reduction Tributary Strategy for the Shenandoah and Potomac River Basins*. Virginia Secretary of Natural Resources, Richmond, Virginia. http://www.naturalresources.virginia.gov/Initiatives/WaterQuality/FinalizedTribStrats/shenandoah.pdf

Weiskel, P.A., B.L. Howes, and G.R. Heufelder. 1996. Coliform contamination of a coastal embayment: sources and transport pathways. *Environ. Sci. Technol*. 30: 1872-1881.

Woods, A.J., J.M. Omernik, and D.D. Brown. 1999. *Level III and IV Ecoregions of Delaware, Maryland, Pennsylvania, Virginia, and West Virginia.* U.S. Environmental Protection Agency, Corvallis, Or.

APPENDIX A:
Hydrologic Model Parameters

Table A-1. Hydrologic Reach Parameters for the Spout Run LSPC Model.

Sub-watershed	Initial Depth (m)	Reach Length (m)	Reach Slope	Bankfull Width (m)	Bankfull Depth (m)	R1[a]	Upper Bank Slope	W1[b]	Manning's N	CRRAT[c]
1	0.1	2147	0.00698649	2.5	0.3	0.75	0.1	0.5	0.04	1.5
2	0.1	2344	0.00767918	2.5	0.3	0.75	0.1	0.5	0.04	1.5
3	0.2	2603	0.00345755	4.5	0.35	0.67	0.1	0.75	0.04	1.5
4	0.2	3856	0.00778008	3.2	0.35	0.67	0.1	0.75	0.04	1.5
5	0.2	1933	0.00413864	8	0.4	0.5	0.07	1.25	0.04	1.5
6	0.55	1267	0.00157853	8.5	0.9	0.65	0.1	0.47	0.04	1.5
7	0.2	3992	0.00726453	5	0.6	0.5	0.2	0.29	0.04	1.5
8	0.2	894	0.00782998	5	0.6	0.5	0.2	0.29	0.04	1.5
9	0.3	4138	0.00459159	4	0.6	0.5	0.2	0.29	0.04	1.5
10	0.1	3061	0.00751388	2.5	0.3	0.75	0.1	0.5	0.04	1.5
11	0.2	3113	0.00835207	2.7	0.6	0.5	0.2	0.29	0.04	1.5
12	0.4	547	0.00731261	8.5	0.5	0.875	0.07	0.125	0.04	1.5
13	0.4	708	0.00564972	8.5	0.5	0.875	0.07	0.125	0.04	1.5
14	0.4	1467	0.00204499	9	0.5	0.875	0.07	0.125	0.04	1.5
15	0.45	1379	0.00652647	10.5	0.75	0.81	0.2	0.48	0.04	1.5
16	0.1	2460	0.0097561	2.5	0.3	0.75	0.1	0.5	0.04	1.5
17	0.45	2919	0.004111	10.5	0.75	0.81	0.2	0.48	0.04	1.5
18	0.1	1501	0.01665556	2.5	0.3	0.75	0.1	0.5	0.04	1.5
19	0.45	1024	0.00292969	10	1.1	1	8	0.15	0.04	1.5
20	0.45	641	0.02340094	10	1.1	1	8	0.15	0.04	1.5

[a] R1 = Ratio of bottom width to bankfull width.
[b] W1 = Ratio of bank width to bankfull width.
[c] CRRAT = Ratio of maximum velocity to mean velocity.

Table A-2. Hydrologic Watershed Parameters for Sub-watersheds 1-5 in the LSPC Model.

Sub-watershed	Land use	SLSUR	LSUR	MELEV	RMELEV
1	Residential	0.039	1040	622	606
	Transitional	0.039	1040	622	606
	Cropland	0.028	1040	622	606
	Pasture/Hay	0.028	1040	622	606
	Degraded Riparian Pasture	0.041	1040	622	606
	Forest	0.037	1040	622	606
	Impervious Urban/Transportation	0.034	1040	622	606
	Impervious Residential	0.039	1040	622	606
	Impervious Transitional	0.039	1040	622	606
	Water	0.000	0	606	606
2	Residential	0.019	698	639	608
	Transitional	0.019	698	639	608
	Cropland	0.039	698	639	608
	Pasture/Hay	0.039	698	639	608
	Degraded Riparian Pasture	0.039	698	639	608
	Forest	0.045	698	639	608
	Impervious Urban/Transportation	0.042	698	639	608
	Impervious Residential	0.019	698	639	608
	Impervious Transitional	0.019	698	639	608
	Water	0.000	0	608	608
3	Residential	0.031	1015	598	567
	Transitional	0.031	1015	598	567
	Cropland	0.041	1015	598	567
	Pasture/Hay	0.041	1015	598	567
	Degraded Riparian Pasture	0.034	1015	598	567
	Forest	0.050	1015	598	567
	Impervious Urban/Transportation	0.036	1015	598	567
	Impervious Residential	0.031	1015	598	567
	Impervious Transitional	0.031	1015	598	567
	Water	0.000	0	567	567
4	Residential	0.047	1376	624	592
	Transitional	0.047	1376	624	592
	Cropland	0.035	1376	624	592
	Pasture/Hay	0.035	1376	624	592
	Degraded Riparian Pasture	0.026	1376	624	592
	Forest	0.036	1376	624	592
	Impervious Urban/Transportation	0.041	1376	624	592
	Impervious Residential	0.047	1376	624	592
	Impervious Transitional	0.047	1376	624	592
	Water	0.000	0	592	592
5	Residential	0.040	3374	589	541
	Transitional	0.040	3374	589	541
	Cropland	0.045	3374	589	541
	Pasture/Hay	0.045	3374	589	541
	Degraded Riparian Pasture	0.023	3374	589	541
	Forest	0.043	3374	589	541
	Impervious Urban/Transportation	0.038	3374	589	541
	Impervious Residential	0.040	3374	589	541
	Impervious Transitional	0.040	3374	589	541
	Water	0.000	0	541	541

Table A-3. Hydrologic Watershed Parameters for Sub-watersheds 6-10 in the LSPC Model.

Sub-watershed	Land use	SLSUR	LSUR	MELEV	RMELEV
6	Residential	0.038	1093	563	523
	Transitional	0.038	1093	563	523
	Cropland	0.073	1093	563	523
	Pasture/Hay	0.073	1093	563	523
	Degraded Riparian Pasture	0.071	1093	563	523
	Forest	0.075	1093	563	523
	Impervious Urban/Transportation	0.038	1093	563	523
	Impervious Residential	0.038	1093	563	523
	Impervious Transitional	0.038	1093	563	523
	Water	0.000	0	523	523
7	Residential	0.037	1527	617	599
	Transitional	0.037	1527	617	599
	Cropland	0.028	1527	617	599
	Pasture/Hay	0.028	1527	617	599
	Degraded Riparian Pasture	0.023	1527	617	599
	Forest	0.029	1527	617	599
	Impervious Urban/Transportation	0.030	1527	617	599
	Impervious Residential	0.037	1527	617	599
	Impervious Transitional	0.037	1527	617	599
	Water	0.000	0	599	599
8	Residential	0.055	575	564	537
	Transitional	0.055	575	564	537
	Cropland	0.068	575	564	537
	Pasture/Hay	0.068	575	564	537
	Degraded Riparian Pasture	0.070	575	564	537
	Forest	0.073	575	564	537
	Impervious Urban/Transportation	0.070	575	564	537
	Impervious Residential	0.055	575	564	537
	Impervious Transitional	0.055	575	564	537
	Water	0.000	0	537	537
9	Residential	0.030	1685	619	585
	Transitional	0.030	1685	619	585
	Cropland	0.039	1685	619	585
	Pasture/Hay	0.039	1685	619	585
	Degraded Riparian Pasture	0.031	1685	619	585
	Forest	0.038	1685	619	585
	Impervious Urban/Transportation	0.040	1685	619	585
	Impervious Residential	0.030	1685	619	585
	Impervious Transitional	0.030	1685	619	585
	Water	0.000	0	585	585
10	Residential	0.022	805	607	589
	Transitional	0.022	805	607	589
	Cropland	0.034	805	607	589
	Pasture/Hay	0.034	805	607	589
	Degraded Riparian Pasture	0.029	805	607	589
	Forest	0.032	805	607	589
	Impervious Urban/Transportation	0.026	805	607	589
	Impervious Residential	0.022	805	607	589
	Impervious Transitional	0.022	805	607	589
	Water	0.000	0	589	589

Table A-4. Hydrologic Watershed Parameters for Sub-watersheds 11-15 in the LSPC Model.

Sub-watershed	Land use	SLSUR	LSUR	MELEV	RMELEV
11	Residential	0.031	809	604	582
	Transitional	0.031	809	604	582
	Cropland	0.034	809	604	582
	Pasture/Hay	0.034	809	604	582
	Degraded Riparian Pasture	0.021	809	604	582
	Forest	0.031	809	604	582
	Impervious Urban/Transportation	0.026	809	604	582
	Impervious Residential	0.031	809	604	582
	Impervious Transitional	0.031	809	604	582
	Water	0.000	0	582	582
12	Residential	0.049	423	561	548
	Transitional	0.049	423	561	548
	Cropland	0.045	423	561	548
	Pasture/Hay	0.045	423	561	548
	Degraded Riparian Pasture	0.049	423	561	548
	Forest	0.052	423	561	548
	Impervious Urban/Transportation	0.049	423	561	548
	Impervious Residential	0.049	423	561	548
	Impervious Transitional	0.049	423	561	548
	Water	0.000	0	548	548
13	Residential	0.061	2868	582	537
	Transitional	0.061	2868	582	537
	Cropland	0.053	2868	582	537
	Pasture/Hay	0.053	2868	582	537
	Degraded Riparian Pasture	0.054	2868	582	537
	Forest	0.057	2868	582	537
	Impervious Urban/Transportation	0.040	2868	582	537
	Impervious Residential	0.061	2868	582	537
	Impervious Transitional	0.061	2868	582	537
	Water	0.000	0	537	537
14	Residential	0.043	725	552	524
	Transitional	0.043	725	552	524
	Cropland	0.062	725	552	524
	Pasture/Hay	0.062	725	552	524
	Degraded Riparian Pasture	0.066	725	552	524
	Forest	0.082	725	552	524
	Impervious Urban/Transportation	0.038	725	552	524
	Impervious Residential	0.043	725	552	524
	Impervious Transitional	0.043	725	552	524
	Water	0.000	0	524	524
15	Residential	0.074	2209	561	502
	Transitional	0.074	2209	561	502
	Cropland	0.077	2209	561	502
	Pasture/Hay	0.077	2209	561	502
	Degraded Riparian Pasture	0.080	2209	561	502
	Forest	0.086	2209	561	502
	Impervious Urban/Transportation	0.071	2209	561	502
	Impervious Residential	0.074	2209	561	502
	Impervious Transitional	0.074	2209	561	502
	Water	0.000	0	502	502

Table A-5. Hydrologic Watershed Parameters for Sub-watersheds 16-20 in the LSPC Model.

Sub-watershed	Land use	SLSUR	LSUR	MELEV	RMELEV
16	Residential	0.060	1866	588	524
	Transitional	0.060	1866	588	524
	Cropland	0.052	1866	588	524
	Pasture/Hay	0.052	1866	588	524
	Degraded Riparian Pasture	0.061	1866	588	524
	Forest	0.082	1866	588	524
	Impervious Urban/Transportation	0.070	1866	588	524
	Impervious Residential	0.060	1866	588	524
	Impervious Transitional	0.060	1866	588	524
	Water	0.000	0	524	524
17	Residential	0.087	1453	526	468
	Transitional	0.087	1453	526	468
	Cropland	0.097	1453	526	468
	Pasture/Hay	0.097	1453	526	468
	Degraded Riparian Pasture	0.101	1453	526	468
	Forest	0.115	1453	526	468
	Impervious Urban/Transportation	0.077	1453	526	468
	Impervious Residential	0.087	1453	526	468
	Impervious Transitional	0.087	1453	526	468
	Water	0.000	0	468	468
18	Residential	0.087	656	536	492
	Transitional	0.087	656	536	492
	Cropland	0.085	656	536	492
	Pasture/Hay	0.085	656	536	492
	Degraded Riparian Pasture	0.087	656	536	492
	Forest	0.100	656	536	492
	Impervious Urban/Transportation	0.087	656	536	492
	Impervious Residential	0.087	656	536	492
	Impervious Transitional	0.087	656	536	492
	Water	0.000	0	492	492
19	Residential	0.107	760	496	445
	Transitional	0.107	760	496	445
	Cropland	0.161	760	496	445
	Pasture/Hay	0.161	760	496	445
	Degraded Riparian Pasture	0.144	760	496	445
	Forest	0.143	760	496	445
	Impervious Urban/Transportation	0.222	760	496	445
	Impervious Residential	0.107	760	496	445
	Impervious Transitional	0.107	760	496	445
	Water	0.000	0	445	445
20	Residential	0.017	357	434	373
	Transitional	0.017	357	434	373
	Cropland	0.058	357	434	373
	Pasture/Hay	0.058	357	434	373
	Degraded Riparian Pasture	0.076	357	434	373
	Forest	0.103	357	434	373
	Impervious Urban/Transportation	0.107	357	434	373
	Impervious Residential	0.017	357	434	373
	Impervious Transitional	0.017	357	434	373
	Water	0.000	0	373	373

Table A-6. Hydrologic Parameter Group 1 for the Spout Run LSPC Model.

Land use	LZSN	INFILT	KVARY	AGWRC
Residential	7.2	0.1584	3.5	0.99522
Transitional	7.2	0.1584	3.5	0.99522
Cropland	7.2	0.2508	3.5	0.99522
Pasture/Hay	7.2	0.2508	3.5	0.99522
Degraded Riparian Pasture	7.2	0.2508	3.5	0.99522
Forest	7.2	0.33	3.5	0.99522
Impervious Urban/Transportation	7.2	0	3.5	0.99522
Impervious Residential	7.2	0	3.5	0.99522
Impervious Transitional	7.2	0	3.5	0.99522
Water	7.2	0	3.5	0.99522

Table A-7. Hydrologic Parameter Group 2 for the Spout Run LSPC Model.

Land use	PETMAX	PETMIN	INFEXP	INFILD	DEEPFR	BASETP	AGWETP
Residential	45	35	2	2	0.448	0.075	0.01
Transitional	45	35	2	2	0.448	0.075	0.01
Cropland	45	35	2	2	0.448	0.075	0.01
Pasture/Hay	45	35	2	2	0.448	0.075	0.01
Degraded Riparian Pasture	45	35	2	2	0.448	0.075	0.01
Forest	45	35	2	2	0.448	0.075	0.01
Impervious Urban/Transportation	45	35	2	2	0.448	0.075	0.01
Impervious Residential	45	35	2	2	0.448	0.075	0.01
Impervious Transitional	45	35	2	2	0.448	0.075	0.01
Water	45	35	2	2	0.448	0.075	0.01

Table A-8. Hydrologic Parameter Group 3 for the Spout Run LSPC Model.

Land use	CEPS	UZSN	NSUR	INTFW	IRC	LZETP
Residential	1	1	0.15	3	0.48	1
Transitional	1	1	0.15	3	0.48	1
Cropland	1	1	0.15	3	0.48	1
Pasture/Hay	1	1	0.15	3	0.48	1
Degraded Riparian Pasture	1	1	0.15	3	0.48	1
Forest	1	1	0.15	3	0.48	1
Impervious Urban/Transportation	1	1	0.15	3	0.48	1
Impervious Residential	1	1	0.15	3	0.48	1
Impervious Transitional	1	1	0.15	3	0.48	1
Water	1	1	0.15	3	0.48	1

Table A-9. Monthly Interception Storage (CEPS) Parameters for the Spout Run LSPC Model.

Land use	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Residential	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Transitional	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Cropland	0.03	0.03	0.03	0.03	0.03	0.3	0.4	0.4	0.4	0.4	0.4	0.4
Pasture/Hay	0.03	0.03	0.03	0.03	0.03	0.3	0.4	0.4	0.4	0.4	0.4	0.4
Degraded Riparian Pasture	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Forest	0.03	0.03	0.03	0.03	0.03	0.3	0.4	0.4	0.4	0.4	0.4	0.4
Impervious Urban/Transportation	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Impervious Residential	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Impervious Transitional	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Water	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03

Table A-10. Monthly Upper Zone Nominal Storage (UZSN) Parameters for the Spout Run LSPC Model.

Land use	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Residential	0.15	0.15	0.15	0.15	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Transitional	0.15	0.15	0.15	0.15	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Cropland	0.15	0.15	0.15	0.15	0.8	0.96	1.92	1.92	1.92	1.92	1.92	1.92
Pasture/Hay	0.15	0.15	0.15	0.15	0.8	0.96	1.92	1.92	1.92	1.92	1.92	1.92
Degraded Riparian Pasture	0.15	0.15	0.15	0.15	0.8	0.96	1.92	1.92	1.92	1.92	1.92	1.92
Forest	0.15	0.15	0.15	0.15	0.8	0.96	1.92	1.92	1.92	1.92	1.92	1.92
Impervious Urban/Transportation	0.15	0.15	0.15	0.15	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Impervious Residential	0.15	0.15	0.15	0.15	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Impervious Transitional	0.15	0.15	0.15	0.15	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Water	0.15	0.15	0.15	0.15	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8

Table A-11. Monthly Lower Zone Evapotranspiration (LZEPT) Parameters for the Spout Run LSPC Model.

Land use	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Residential	0.2	0.2	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.3
Transitional	0.2	0.2	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.3
Cropland	0.2	0.2	0.2	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.6
Pasture/Hay	0.2	0.2	0.2	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.6
Degraded Riparian Pasture	0.2	0.2	0.2	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.6
Forest	0.2	0.2	0.2	0.85	0.9	0.9	0.9	0.9	0.9	0.9	0.85	0.7
Impervious Urban/Transportation	0.2	0.2	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.3
Impervious Residential	0.2	0.2	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.3
Impervious Transitional	0.2	0.2	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.3
Water	0.2	0.2	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.3

APPENDIX B:
Bacteria Model Parameters

Table B-1. Final Calibrated Bacteria Parameters for the Spout Run LSPC Model.

Parameter	Parameter Description	Calibrated Value
WSQOP	Rate of surface runoff which will remove 90% of stored pollutant	0.18
IOQC	Concentration of pollutant in interflow	0
AOQC	Concentration of pollutant in active groundwater	0
ACQOPM (MON-ACCUM)	Monthly parameter for rate of accumulation of pollutant	See Table B-2
SQOLIM	Monthly parameter for maximum storage of pollutant	See Table B-3
FSTDEC	First order decay rate for pollutant	0.85
THFST	Temperature correction coefficient for first order decay of pollutant	1.07

Table B-2. Monthly Accumulation Table for Fecal Coliform Loading to Spout Run Watershed Under Existing Conditions (cfu/acre/d).

Sub-watershed	Landuse	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Residential (pervious)	2.61E+09	2.61E+09	2.61E+09	2.59E+09	2.59E+09	2.59E+09	2.59E+09	2.59E+09	2.59E+09	2.61E+09	2.61E+09	2.61E+09
1	Transitional (pervious)	9.56E+07	9.56E+07	9.56E+07	7.38E+07	7.38E+07	7.38E+07	7.38E+07	7.38E+07	7.38E+07	9.56E+07	9.56E+07	9.56E+07
1	Cropland	1.01E+08	1.01E+08	1.01E+08	7.89E+07	7.89E+07	7.89E+07	7.89E+07	7.89E+07	7.89E+07	1.01E+08	1.01E+08	1.01E+08
1	Pasture	1.62E+10	1.62E+10	1.62E+10	1.62E+10	1.62E+10	1.62E+10	1.62E+10	1.62E+10	1.62E+10	1.62E+10	1.62E+10	1.62E+10
1	Degraded Riparian Pasture	1.62E+10	1.62E+10	1.62E+10	1.62E+10	1.62E+10	1.62E+10	1.62E+10	1.62E+10	1.62E+10	1.62E+10	1.62E+10	1.62E+10
1	Forest	1.01E+08	1.01E+08	1.01E+08	7.89E+07	7.89E+07	7.89E+07	7.89E+07	7.89E+07	7.89E+07	1.01E+08	1.01E+08	1.01E+08
1	Urban/Transportation (impervious)	9.47E+07	9.47E+07	9.47E+07	7.29E+07	7.29E+07	7.29E+07	7.29E+07	7.29E+07	7.29E+07	9.47E+07	9.47E+07	9.47E+07
1	Residential (impervious)	2.61E+09	2.61E+09	2.61E+09	2.59E+09	2.59E+09	2.59E+09	2.59E+09	2.59E+09	2.59E+09	2.61E+09	2.61E+09	2.61E+09
1	Transitional (impervious)	9.56E+07	9.56E+07	9.56E+07	7.38E+07	7.38E+07	7.38E+07	7.38E+07	7.38E+07	7.38E+07	9.56E+07	9.56E+07	9.56E+07
2	Residential (pervious)	5.08E+09	5.08E+09	5.08E+09	5.06E+09	5.06E+09	5.06E+09	5.06E+09	5.06E+09	5.06E+09	5.08E+09	5.08E+09	5.08E+09
2	Transitional (pervious)	1.12E+08	1.12E+08	1.12E+08	8.87E+07	8.87E+07	8.87E+07	8.87E+07	8.87E+07	8.87E+07	1.12E+08	1.12E+08	1.12E+08
2	Cropland	1.14E+08	1.14E+08	1.14E+08	2.73E+08	7.71E+08	1.54E+09	2.08E+09	1.04E+09	1.10E+09	7.04E+08	1.73E+09	5.37E+08
2	Pasture	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.62E+10	1.61E+10
2	Degraded Riparian Pasture	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10
2	Forest	1.14E+08	1.14E+08	1.14E+08	8.98E+07	8.98E+07	8.98E+07	8.98E+07	8.98E+07	8.98E+07	1.14E+08	1.14E+08	1.14E+08
2	Urban/Transportation (impervious)	1.12E+08	1.12E+08	1.12E+08	8.77E+07	8.77E+07	8.77E+07	8.77E+07	8.77E+07	8.77E+07	1.12E+08	1.12E+08	1.12E+08
2	Residential (impervious)	5.08E+09	5.08E+09	5.08E+09	5.06E+09	5.06E+09	5.06E+09	5.06E+09	5.06E+09	5.06E+09	5.08E+09	5.08E+09	5.08E+09
2	Transitional (impervious)	1.12E+08	1.12E+08	1.12E+08	8.87E+07	8.87E+07	8.87E+07	8.87E+07	8.87E+07	8.87E+07	1.12E+08	1.12E+08	1.12E+08
3	Residential (pervious)	7.55E+08	7.55E+08	7.55E+08	7.35E+08	7.35E+08	7.35E+08	7.35E+08	7.35E+08	7.35E+08	7.55E+08	7.55E+08	7.55E+08
3	Transitional (pervious)	9.78E+07	9.78E+07	9.78E+07	7.82E+07	7.82E+07	7.82E+07	7.82E+07	7.82E+07	7.82E+07	9.78E+07	9.78E+07	9.78E+07
3	Cropland	1.01E+08	1.01E+08	1.01E+08	1.40E+08	3.00E+08	5.46E+08	7.19E+08	3.85E+08	4.04E+08	2.90E+08	6.19E+08	2.36E+08
3	Pasture	1.63E+10	1.63E+10	1.63E+10	1.63E+10	1.63E+10	1.64E+10	1.65E+10	1.63E+10	1.64E+10	1.63E+10	1.64E+10	1.63E+10
3	Degraded Riparian Pasture	1.63E+10	1.63E+10	1.63E+10	1.62E+10	1.62E+10	1.62E+10	1.62E+10	1.62E+10	1.62E+10	1.63E+10	1.63E+10	1.63E+10
3	Forest	1.01E+08	1.01E+08	1.01E+08	8.09E+07	8.09E+07	8.09E+07	8.09E+07	8.09E+07	8.09E+07	1.01E+08	1.01E+08	1.01E+08
3	Urban/Transportation (impervious)	9.69E+07	9.69E+07	9.69E+07	7.72E+07	7.72E+07	7.72E+07	7.72E+07	7.72E+07	7.72E+07	9.69E+07	9.69E+07	9.69E+07
3	Residential (impervious)	7.55E+08	7.55E+08	7.55E+08	7.35E+08	7.35E+08	7.35E+08	7.35E+08	7.35E+08	7.35E+08	7.55E+08	7.55E+08	7.55E+08
3	Transitional (impervious)	9.78E+07	9.78E+07	9.78E+07	7.82E+07	7.82E+07	7.82E+07	7.82E+07	7.82E+07	7.82E+07	9.78E+07	9.78E+07	9.78E+07
4	Residential (pervious)	2.57E+09	2.57E+09	2.57E+09	2.55E+09	2.55E+09	2.55E+09	2.55E+09	2.55E+09	2.55E+09	2.57E+09	2.57E+09	2.57E+09
4	Transitional (pervious)	8.67E+07	8.67E+07	8.67E+07	6.95E+07	6.95E+07	6.95E+07	6.95E+07	6.95E+07	6.95E+07	8.67E+07	8.67E+07	8.67E+07
4	Cropland	8.74E+07	8.74E+07	8.74E+07	1.13E+08	2.30E+08	4.09E+08	5.35E+08	2.92E+08	3.06E+08	2.26E+08	4.65E+08	1.86E+08

4	Pasture	2.84E+10	2.84E+10	2.84E+10	2.84E+10	2.84E+10	2.85E+10	2.85E+10	2.85E+10	2.85E+10	2.84E+10	2.85E+10	2.84E+10
4	Degraded Riparian Pasture	2.84E+10	2.84E+10	2.84E+10	2.84E+10	2.84E+10	2.84E+10	2.84E+10	2.84E+10	2.84E+10	2.84E+10	2.84E+10	2.84E+10
4	Forest	8.74E+07	8.74E+07	8.74E+07	7.02E+07	7.02E+07	7.02E+07	7.02E+07	7.02E+07	7.02E+07	8.74E+07	8.74E+07	8.74E+07
4	Urban/Transportation (impervious)	8.57E+07	8.57E+07	8.57E+07	6.86E+07	6.86E+07	6.86E+07	6.86E+07	6.86E+07	6.86E+07	8.57E+07	8.57E+07	8.57E+07
4	Residential (impervious)	2.57E+09	2.57E+09	2.57E+09	2.55E+09	2.55E+09	2.55E+09	2.55E+09	2.55E+09	2.55E+09	2.57E+09	2.57E+09	2.57E+09
4	Transitional (impervious)	8.67E+07	8.67E+07	8.67E+07	6.95E+07	6.95E+07	6.95E+07	6.95E+07	6.95E+07	6.95E+07	8.67E+07	8.67E+07	8.67E+07
5	Residential (pervious)	1.80E+09	1.80E+09	1.80E+09	1.79E+09	1.79E+09	1.79E+09	1.79E+09	1.79E+09	1.79E+09	1.80E+09	1.80E+09	1.80E+09
5	Transitional (pervious)	5.68E+07	5.68E+07	5.68E+07	4.93E+07	4.93E+07	4.93E+07	4.93E+07	4.93E+07	4.93E+07	5.68E+07	5.68E+07	5.68E+07
5	Cropland	5.75E+07	5.75E+07	5.75E+07	8.58E+07	1.83E+08	3.33E+08	4.38E+08	2.35E+08	2.47E+08	1.73E+08	3.73E+08	1.40E+08
5	Pasture	1.62E+10	1.62E+10	1.62E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.62E+10	1.62E+10	1.62E+10
5	Degraded Riparian Pasture	1.62E+10	1.62E+10	1.62E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.62E+10	1.62E+10	1.62E+10
5	Forest	5.75E+07	5.75E+07	5.75E+07	5.00E+07	5.00E+07	5.00E+07	5.00E+07	5.00E+07	5.00E+07	5.75E+07	5.75E+07	5.75E+07
5	Urban/Transportation (impervious)	5.59E+07	5.59E+07	5.59E+07	4.84E+07	4.84E+07	4.84E+07	4.84E+07	4.84E+07	4.84E+07	5.59E+07	5.59E+07	5.59E+07
5	Residential (impervious)	1.80E+09	1.80E+09	1.80E+09	1.79E+09	1.79E+09	1.79E+09	1.79E+09	1.79E+09	1.79E+09	1.80E+09	1.80E+09	1.80E+09
5	Transitional (impervious)	5.68E+07	5.68E+07	5.68E+07	4.93E+07	4.93E+07	4.93E+07	4.93E+07	4.93E+07	4.93E+07	5.68E+07	5.68E+07	5.68E+07
6	Residential (pervious)	7.88E+08	7.88E+08	7.88E+08	7.69E+08	7.69E+08	7.69E+08	7.69E+08	7.69E+08	7.69E+08	7.88E+08	7.88E+08	7.88E+08
6	Transitional (pervious)	8.48E+07	8.48E+07	8.48E+07	6.61E+07	6.61E+07	6.61E+07	6.61E+07	6.61E+07	6.61E+07	8.48E+07	8.48E+07	8.48E+07
6	Cropland	9.34E+07	9.34E+07	9.34E+07	7.47E+07	7.47E+07	7.47E+07	7.47E+07	7.47E+07	7.47E+07	9.34E+07	9.34E+07	9.34E+07
6	Pasture	1.60E+10	1.60E+10	1.60E+10	1.59E+10	1.59E+10	1.58E+10	1.58E+10	1.58E+10	1.59E+10	1.60E+10	1.60E+10	1.60E+10
6	Degraded Riparian Pasture	1.60E+10	1.60E+10	1.60E+10	1.59E+10	1.59E+10	1.58E+10	1.58E+10	1.58E+10	1.59E+10	1.60E+10	1.60E+10	1.60E+10
6	Forest	9.34E+07	9.34E+07	9.34E+07	7.47E+07	7.47E+07	7.47E+07	7.47E+07	7.47E+07	7.47E+07	9.34E+07	9.34E+07	9.34E+07
6	Urban/Transportation (impervious)	8.39E+07	8.39E+07	8.39E+07	6.52E+07	6.52E+07	6.52E+07	6.52E+07	6.52E+07	6.52E+07	8.39E+07	8.39E+07	8.39E+07
6	Residential (impervious)	7.88E+08	7.88E+08	7.88E+08	7.69E+08	7.69E+08	7.69E+08	7.69E+08	7.69E+08	7.69E+08	7.88E+08	7.88E+08	7.88E+08
6	Transitional (impervious)	8.48E+07	8.48E+07	8.48E+07	6.61E+07	6.61E+07	6.61E+07	6.61E+07	6.61E+07	6.61E+07	8.48E+07	8.48E+07	8.48E+07
7	Residential (pervious)	2.92E+09	2.92E+09	2.92E+09	2.90E+09	2.90E+09	2.90E+09	2.90E+09	2.90E+09	2.90E+09	2.92E+09	2.92E+09	2.92E+09
7	Transitional (pervious)	8.93E+07	8.93E+07	8.93E+07	7.23E+07	7.23E+07	7.23E+07	7.23E+07	7.23E+07	7.23E+07	8.93E+07	8.93E+07	8.93E+07
7	Cropland	9.13E+07	9.13E+07	9.13E+07	4.04E+10	4.06E+10	5.39E+08	7.12E+08	3.79E+08	3.98E+08	2.81E+08	6.10E+08	2.27E+08
7	Pasture	1.62E+10	1.62E+10	1.62E+10	1.79E+10	1.80E+10	1.62E+10	1.62E+10	1.62E+10	1.62E+10	1.62E+10	1.62E+10	1.62E+10
7	Degraded Riparian Pasture	1.62E+10	1.62E+10	1.62E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.62E+10	1.62E+10	1.62E+10
7	Forest	9.13E+07	9.13E+07	9.13E+07	7.43E+07	7.43E+07	7.43E+07	7.43E+07	7.43E+07	7.43E+07	9.13E+07	9.13E+07	9.13E+07
7	Urban/Transportation (impervious)	8.84E+07	8.84E+07	8.84E+07	7.13E+07	7.13E+07	7.13E+07	7.13E+07	7.13E+07	7.13E+07	8.84E+07	8.84E+07	8.84E+07
7	Residential (impervious)	2.92E+09	2.92E+09	2.92E+09	2.90E+09	2.90E+09	2.90E+09	2.90E+09	2.90E+09	2.90E+09	2.92E+09	2.92E+09	2.92E+09
7	Transitional (impervious)	8.93E+07	8.93E+07	8.93E+07	7.23E+07	7.23E+07	7.23E+07	7.23E+07	7.23E+07	7.23E+07	8.93E+07	8.93E+07	8.93E+07

8	Residential (pervious)	1.25E+09	1.25E+09	1.25E+09	1.22E+09	1.22E+09	1.22E+09	1.22E+09	1.22E+09	1.22E+09	1.25E+09	1.25E+09	1.25E+09
8	Transitional (pervious)	1.20E+08	1.20E+08	1.20E+08	9.48E+07	9.48E+07	9.48E+07	9.48E+07	9.48E+07	9.48E+07	1.20E+08	1.20E+08	1.20E+08
8	Cropland	1.26E+08	1.26E+08	1.26E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.26E+08	1.26E+08	1.26E+08
8	Pasture	1.53E+10	1.53E+10	1.53E+10	1.53E+10	1.53E+10	1.53E+10	1.53E+10	1.53E+10	1.53E+10	1.53E+10	1.53E+10	1.53E+10
8	Degraded Riparian Pasture	1.53E+10	1.53E+10	1.53E+10	1.53E+10	1.53E+10	1.53E+10	1.53E+10	1.53E+10	1.53E+10	1.53E+10	1.53E+10	1.53E+10
8	Forest	1.26E+08	1.26E+08	1.26E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.26E+08	1.26E+08	1.26E+08
8	Urban/Transportation (impervious)	1.19E+08	1.19E+08	1.19E+08	9.40E+07	9.40E+07	9.40E+07	9.40E+07	9.40E+07	9.40E+07	1.19E+08	1.19E+08	1.19E+08
8	Residential (impervious)	1.25E+09	1.25E+09	1.25E+09	1.22E+09	1.22E+09	1.22E+09	1.22E+09	1.22E+09	1.22E+09	1.25E+09	1.25E+09	1.25E+09
8	Transitional (impervious)	1.20E+08	1.20E+08	1.20E+08	9.48E+07	9.48E+07	9.48E+07	9.48E+07	9.48E+07	9.48E+07	1.20E+08	1.20E+08	1.20E+08
9	Residential (pervious)	7.74E+08	7.74E+08	7.74E+08	7.57E+08	7.57E+08	7.57E+08	7.57E+08	7.57E+08	7.57E+08	7.74E+08	7.74E+08	7.74E+08
9	Transitional (pervious)	9.06E+07	9.06E+07	9.06E+07	7.38E+07	7.38E+07	7.38E+07	7.38E+07	7.38E+07	7.38E+07	9.06E+07	9.06E+07	9.06E+07
9	Cropland	9.24E+07	9.24E+07	9.24E+07	1.47E+08	3.39E+08	6.36E+08	8.45E+08	4.43E+08	4.66E+08	3.21E+08	7.18E+08	2.56E+08
9	Pasture	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.62E+10	1.61E+10
9	Degraded Riparian Pasture	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10
9	Forest	9.24E+07	9.24E+07	9.24E+07	7.57E+07	7.57E+07	7.57E+07	7.57E+07	7.57E+07	7.57E+07	9.24E+07	9.24E+07	9.24E+07
9	Urban/Transportation (impervious)	8.96E+07	8.96E+07	8.96E+07	7.29E+07	7.29E+07	7.29E+07	7.29E+07	7.29E+07	7.29E+07	8.96E+07	8.96E+07	8.96E+07
9	Residential (impervious)	7.74E+08	7.74E+08	7.74E+08	7.57E+08	7.57E+08	7.57E+08	7.57E+08	7.57E+08	7.57E+08	7.74E+08	7.74E+08	7.74E+08
9	Transitional (impervious)	9.06E+07	9.06E+07	9.06E+07	7.38E+07	7.38E+07	7.38E+07	7.38E+07	7.38E+07	7.38E+07	9.06E+07	9.06E+07	9.06E+07
10	Residential (pervious)	8.28E+08	8.28E+08	8.28E+08	8.02E+08	8.02E+08	8.02E+08	8.02E+08	8.02E+08	8.02E+08	8.28E+08	8.28E+08	8.28E+08
10	Transitional (pervious)	1.25E+08	1.25E+08	1.25E+08	9.85E+07	9.85E+07	9.85E+07	9.85E+07	9.85E+07	9.85E+07	1.25E+08	1.25E+08	1.25E+08
10	Cropland	1.28E+08	1.28E+08	1.28E+08	4.04E+10	4.06E+10	4.42E+08	5.69E+08	3.24E+08	3.38E+08	2.67E+08	5.08E+08	2.27E+08
10	Pasture	1.61E+10	1.61E+10	1.61E+10	1.74E+10	1.74E+10	1.62E+10	1.62E+10	1.61E+10	1.61E+10	1.62E+10	1.62E+10	1.62E+10
10	Degraded Riparian Pasture	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10
10	Forest	1.28E+08	1.28E+08	1.28E+08	1.01E+08	1.01E+08	1.01E+08	1.01E+08	1.01E+08	1.01E+08	1.28E+08	1.28E+08	1.28E+08
10	Urban/Transportation (impervious)	1.24E+08	1.24E+08	1.24E+08	9.75E+07	9.75E+07	9.75E+07	9.75E+07	9.75E+07	9.75E+07	1.24E+08	1.24E+08	1.24E+08
10	Residential (impervious)	8.28E+08	8.28E+08	8.28E+08	8.02E+08	8.02E+08	8.02E+08	8.02E+08	8.02E+08	8.02E+08	8.28E+08	8.28E+08	8.28E+08
10	Transitional (impervious)	1.25E+08	1.25E+08	1.25E+08	9.85E+07	9.85E+07	9.85E+07	9.85E+07	9.85E+07	9.85E+07	1.25E+08	1.25E+08	1.25E+08
11	Residential (pervious)	1.30E+09	1.30E+09	1.30E+09	1.27E+09	1.27E+09	1.27E+09	1.27E+09	1.27E+09	1.27E+09	1.30E+09	1.30E+09	1.30E+09
11	Transitional (pervious)	1.13E+08	1.13E+08	1.13E+08	8.72E+07	8.72E+07	8.72E+07	8.72E+07	8.72E+07	8.72E+07	1.13E+08	1.13E+08	1.13E+08
11	Cropland	1.15E+08	1.15E+08	1.15E+08	4.04E+10	4.04E+10	2.02E+08	2.44E+08	1.63E+08	1.68E+08	1.61E+08	2.41E+08	1.48E+08
11	Pasture	1.61E+10	1.61E+10	1.61E+10	2.59E+10	2.59E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.61E+10	1.61E+10	1.61E+10
11	Degraded Riparian Pasture	1.61E+10	1.61E+10	1.61E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.61E+10	1.61E+10	1.61E+10
11	Forest	1.15E+08	1.15E+08	1.15E+08	8.90E+07	8.90E+07	8.90E+07	8.90E+07	8.90E+07	8.90E+07	1.15E+08	1.15E+08	1.15E+08
11	Urban/Transportation	1.12E+08	1.12E+08	1.12E+08	8.64E+07	8.64E+07	8.64E+07	8.64E+07	8.64E+07	8.64E+07	1.12E+08	1.12E+08	1.12E+08

	(impervious)												
11	Residential (impervious)	1.30E+09	1.30E+09	1.30E+09	1.27E+09	1.27E+09	1.27E+09	1.27E+09	1.27E+09	1.27E+09	1.30E+09	1.30E+09	1.30E+09
11	Transitional (impervious)	1.13E+08	1.13E+08	1.13E+08	8.72E+07	8.72E+07	8.72E+07	8.72E+07	8.72E+07	8.72E+07	1.13E+08	1.13E+08	1.13E+08
12	Residential (pervious)	1.62E+08	1.62E+08	1.62E+08	1.49E+08	1.49E+08	1.49E+08	1.49E+08	1.49E+08	1.49E+08	1.62E+08	1.62E+08	1.62E+08
12	Transitional (pervious)	1.64E+08	1.64E+08	1.64E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.64E+08	1.64E+08	1.64E+08
12	Cropland	1.72E+08	1.72E+08	1.72E+08	1.58E+08	1.58E+08	1.58E+08	1.58E+08	1.58E+08	1.58E+08	1.72E+08	1.72E+08	1.72E+08
12	Pasture	1.61E+10	1.61E+10	1.61E+10	1.60E+10	1.60E+10	1.59E+10	1.59E+10	1.59E+10	1.60E+10	1.61E+10	1.61E+10	1.61E+10
12	Degraded Riparian Pasture	1.61E+10	1.61E+10	1.61E+10	1.60E+10	1.60E+10	1.59E+10	1.59E+10	1.59E+10	1.60E+10	1.61E+10	1.61E+10	1.61E+10
12	Forest	1.72E+08	1.72E+08	1.72E+08	1.58E+08	1.58E+08	1.58E+08	1.58E+08	1.58E+08	1.58E+08	1.72E+08	1.72E+08	1.72E+08
12	Urban/Transportation (impervious)	1.62E+08	1.62E+08	1.62E+08	1.49E+08	1.49E+08	1.49E+08	1.49E+08	1.49E+08	1.49E+08	1.62E+08	1.62E+08	1.62E+08
12	Residential (impervious)	1.62E+08	1.62E+08	1.62E+08	1.49E+08	1.49E+08	1.49E+08	1.49E+08	1.49E+08	1.49E+08	1.62E+08	1.62E+08	1.62E+08
12	Transitional (impervious)	1.64E+08	1.64E+08	1.64E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.64E+08	1.64E+08	1.64E+08
13	Residential (pervious)	8.26E+08	8.26E+08	8.26E+08	8.20E+08	8.20E+08	8.20E+08	8.20E+08	8.20E+08	8.20E+08	8.26E+08	8.26E+08	8.26E+08
13	Transitional (pervious)	5.54E+07	5.54E+07	5.54E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07	5.54E+07	5.54E+07	5.54E+07
13	Cropland	5.72E+07	5.72E+07	5.72E+07	5.08E+07	5.08E+07	5.08E+07	5.08E+07	5.08E+07	5.08E+07	5.72E+07	5.72E+07	5.72E+07
13	Pasture	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10
13	Degraded Riparian Pasture	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10
13	Forest	5.72E+07	5.72E+07	5.72E+07	5.08E+07	5.08E+07	5.08E+07	5.08E+07	5.08E+07	5.08E+07	5.72E+07	5.72E+07	5.72E+07
13	Urban/Transportation (impervious)	5.44E+07	5.44E+07	5.44E+07	4.80E+07	4.80E+07	4.80E+07	4.80E+07	4.80E+07	4.80E+07	5.44E+07	5.44E+07	5.44E+07
13	Residential (impervious)	8.26E+08	8.26E+08	8.26E+08	8.20E+08	8.20E+08	8.20E+08	8.20E+08	8.20E+08	8.20E+08	8.26E+08	8.26E+08	8.26E+08
13	Transitional (impervious)	5.54E+07	5.54E+07	5.54E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07	5.54E+07	5.54E+07	5.54E+07
14	Residential (pervious)	3.88E+08	3.88E+08	3.88E+08	3.64E+08	3.64E+08	3.64E+08	3.64E+08	3.64E+08	3.64E+08	3.88E+08	3.88E+08	3.88E+08
14	Transitional (pervious)	1.12E+08	1.12E+08	1.12E+08	8.78E+07	8.78E+07	8.78E+07	8.78E+07	8.78E+07	8.78E+07	1.12E+08	1.12E+08	1.12E+08
14	Cropland	1.19E+08	1.19E+08	1.19E+08	9.50E+07	9.50E+07	9.50E+07	9.50E+07	9.50E+07	9.50E+07	1.19E+08	1.19E+08	1.19E+08
14	Pasture	1.64E+10	1.64E+10	1.64E+10	1.63E+10	1.63E+10	1.63E+10	1.63E+10	1.63E+10	1.63E+10	1.64E+10	1.64E+10	1.64E+10
14	Degraded Riparian Pasture	1.64E+10	1.64E+10	1.64E+10	1.63E+10	1.63E+10	1.63E+10	1.63E+10	1.63E+10	1.63E+10	1.64E+10	1.64E+10	1.64E+10
14	Forest	1.19E+08	1.19E+08	1.19E+08	9.50E+07	9.50E+07	9.50E+07	9.50E+07	9.50E+07	9.50E+07	1.19E+08	1.19E+08	1.19E+08
14	Urban/Transportation (impervious)	1.11E+08	1.11E+08	1.11E+08	8.70E+07	8.70E+07	8.70E+07	8.70E+07	8.70E+07	8.70E+07	1.11E+08	1.11E+08	1.11E+08
14	Residential (impervious)	3.88E+08	3.88E+08	3.88E+08	3.64E+08	3.64E+08	3.64E+08	3.64E+08	3.64E+08	3.64E+08	3.88E+08	3.88E+08	3.88E+08
14	Transitional (impervious)	1.12E+08	1.12E+08	1.12E+08	8.78E+07	8.78E+07	8.78E+07	8.78E+07	8.78E+07	8.78E+07	1.12E+08	1.12E+08	1.12E+08
15	Residential (pervious)	2.63E+09	2.63E+09	2.63E+09	2.62E+09	2.62E+09	2.62E+09	2.62E+09	2.62E+09	2.62E+09	2.63E+09	2.63E+09	2.63E+09
15	Transitional (pervious)	6.11E+07	6.11E+07	6.11E+07	5.25E+07	5.25E+07	5.25E+07	5.25E+07	5.25E+07	5.25E+07	6.11E+07	6.11E+07	6.11E+07
15	Cropland	6.45E+07	6.45E+07	6.45E+07	4.04E+10	4.04E+10	5.60E+07	5.60E+07	5.60E+07	5.60E+07	6.45E+07	6.45E+07	6.45E+07
15	Pasture	1.61E+10	1.61E+10	1.61E+10	1.66E+10	1.66E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10

15	Degraded Riparian Pasture	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10
15	Forest	6.45E+07	6.45E+07	6.45E+07	5.60E+07	5.60E+07	5.60E+07	5.60E+07	5.60E+07	5.60E+07	6.45E+07	6.45E+07	6.45E+07
15	Urban/Transportation (impervious)	6.01E+07	6.01E+07	6.01E+07	5.16E+07	5.16E+07	5.16E+07	5.16E+07	5.16E+07	5.16E+07	6.01E+07	6.01E+07	6.01E+07
15	Residential (impervious)	2.63E+09	2.63E+09	2.63E+09	2.62E+09	2.62E+09	2.62E+09	2.62E+09	2.62E+09	2.62E+09	2.63E+09	2.63E+09	2.63E+09
15	Transitional (impervious)	6.11E+07	6.11E+07	6.11E+07	5.25E+07	5.25E+07	5.25E+07	5.25E+07	5.25E+07	5.25E+07	6.11E+07	6.11E+07	6.11E+07
16	Residential (pervious)	8.53E+08	8.53E+08	8.53E+08	8.41E+08	8.41E+08	8.41E+08	8.41E+08	8.41E+08	8.41E+08	8.53E+08	8.53E+08	8.53E+08
16	Transitional (pervious)	7.32E+07	7.32E+07	7.32E+07	6.19E+07	6.19E+07	6.19E+07	6.19E+07	6.19E+07	6.19E+07	7.32E+07	7.32E+07	7.32E+07
16	Cropland	7.54E+07	7.54E+07	7.54E+07	5.24E+10	5.24E+10	1.98E+08	2.48E+08	1.52E+08	1.57E+08	1.79E+10	1.80E+10	1.15E+08
16	Pasture	1.61E+10	1.61E+10	1.61E+10	1.80E+10	1.80E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.87E+10	1.87E+10	1.61E+10
16	Degraded Riparian Pasture	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10
16	Forest	7.54E+07	7.54E+07	7.54E+07	6.40E+07	6.40E+07	6.40E+07	6.40E+07	6.40E+07	6.40E+07	7.54E+07	7.54E+07	7.54E+07
16	Urban/Transportation (impervious)	7.23E+07	7.23E+07	7.23E+07	6.10E+07	6.10E+07	6.10E+07	6.10E+07	6.10E+07	6.10E+07	7.23E+07	7.23E+07	7.23E+07
16	Residential (impervious)	8.53E+08	8.53E+08	8.53E+08	8.41E+08	8.41E+08	8.41E+08	8.41E+08	8.41E+08	8.41E+08	8.53E+08	8.53E+08	8.53E+08
16	Transitional (impervious)	7.32E+07	7.32E+07	7.32E+07	6.19E+07	6.19E+07	6.19E+07	6.19E+07	6.19E+07	6.19E+07	7.32E+07	7.32E+07	7.32E+07
17	Residential (pervious)	2.89E+09	2.89E+09	2.89E+09	2.88E+09	2.88E+09	2.88E+09	2.88E+09	2.88E+09	2.88E+09	2.89E+09	2.89E+09	2.89E+09
17	Transitional (pervious)	7.66E+07	7.66E+07	7.66E+07	6.44E+07	6.44E+07	6.44E+07	6.44E+07	6.44E+07	6.44E+07	7.66E+07	7.66E+07	7.66E+07
17	Cropland	7.92E+07	7.92E+07	7.92E+07	1.11E+08	2.30E+08	4.13E+08	5.42E+08	2.94E+08	3.08E+08	2.20E+08	4.65E+08	1.80E+08
17	Pasture	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10
17	Degraded Riparian Pasture	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10
17	Forest	7.92E+07	7.92E+07	7.92E+07	6.70E+07	6.70E+07	6.70E+07	6.70E+07	6.70E+07	6.70E+07	7.92E+07	7.92E+07	7.92E+07
17	Urban/Transportation (impervious)	7.57E+07	7.57E+07	7.57E+07	6.34E+07	6.34E+07	6.34E+07	6.34E+07	6.34E+07	6.34E+07	7.57E+07	7.57E+07	7.57E+07
17	Residential (impervious)	2.89E+09	2.89E+09	2.89E+09	2.88E+09	2.88E+09	2.88E+09	2.88E+09	2.88E+09	2.88E+09	2.89E+09	2.89E+09	2.89E+09
17	Transitional (impervious)	7.66E+07	7.66E+07	7.66E+07	6.44E+07	6.44E+07	6.44E+07	6.44E+07	6.44E+07	6.44E+07	7.66E+07	7.66E+07	7.66E+07
18	Residential (pervious)	5.94E+09	5.94E+09	5.94E+09	5.91E+09	5.91E+09	5.91E+09	5.91E+09	5.91E+09	5.91E+09	5.94E+09	5.94E+09	5.94E+09
18	Transitional (pervious)	1.33E+08	1.33E+08	1.33E+08	9.70E+07	9.70E+07	9.70E+07	9.70E+07	9.70E+07	9.70E+07	1.33E+08	1.33E+08	1.33E+08
18	Cropland	1.47E+08	1.47E+08	1.47E+08	1.11E+08	1.11E+08	1.11E+08	1.11E+08	1.11E+08	1.11E+08	1.47E+08	1.47E+08	1.47E+08
18	Pasture	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10
18	Degraded Riparian Pasture	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10
18	Forest	1.47E+08	1.47E+08	1.47E+08	1.11E+08	1.11E+08	1.11E+08	1.11E+08	1.11E+08	1.11E+08	1.47E+08	1.47E+08	1.47E+08
18	Urban/Transportation (impervious)	1.33E+08	1.33E+08	1.33E+08	9.63E+07	9.63E+07	9.63E+07	9.63E+07	9.63E+07	9.63E+07	1.33E+08	1.33E+08	1.33E+08
18	Residential (impervious)	5.94E+09	5.94E+09	5.94E+09	5.91E+09	5.91E+09	5.91E+09	5.91E+09	5.91E+09	5.91E+09	5.94E+09	5.94E+09	5.94E+09
18	Transitional (impervious)	1.33E+08	1.33E+08	1.33E+08	9.70E+07	9.70E+07	9.70E+07	9.70E+07	9.70E+07	9.70E+07	1.33E+08	1.33E+08	1.33E+08
19	Residential (pervious)	7.97E+08	7.97E+08	7.97E+08	7.77E+08	7.77E+08	7.77E+08	7.77E+08	7.77E+08	7.77E+08	7.97E+08	7.97E+08	7.97E+08

19	Transitional (pervious)	1.08E+08	1.08E+08	1.08E+08	8.70E+07	8.70E+07	8.70E+07	8.70E+07	8.70E+07	8.70E+07	1.08E+08	1.08E+08	1.08E+08
19	Cropland	1.12E+08	1.12E+08	1.12E+08	9.07E+07	9.07E+07	9.07E+07	9.07E+07	9.07E+07	9.07E+07	1.12E+08	1.12E+08	1.12E+08
19	Pasture	1.71E+10	1.71E+10	1.71E+10	1.71E+10	1.71E+10	1.71E+10	1.71E+10	1.71E+10	1.71E+10	1.71E+10	1.71E+10	1.71E+10
19	Degraded Riparian Pasture	1.71E+10	1.71E+10	1.71E+10	1.71E+10	1.71E+10	1.71E+10	1.71E+10	1.71E+10	1.71E+10	1.71E+10	1.71E+10	1.71E+10
19	Forest	1.12E+08	1.12E+08	1.12E+08	9.07E+07	9.07E+07	9.07E+07	9.07E+07	9.07E+07	9.07E+07	1.12E+08	1.12E+08	1.12E+08
19	Urban/Transportation (impervious)	1.07E+08	1.07E+08	1.07E+08	8.60E+07	8.60E+07	8.60E+07	8.60E+07	8.60E+07	8.60E+07	1.07E+08	1.07E+08	1.07E+08
19	Residential (impervious)	7.97E+08	7.97E+08	7.97E+08	7.77E+08	7.77E+08	7.77E+08	7.77E+08	7.77E+08	7.77E+08	7.97E+08	7.97E+08	7.97E+08
19	Transitional (impervious)	1.08E+08	1.08E+08	1.08E+08	8.70E+07	8.70E+07	8.70E+07	8.70E+07	8.70E+07	8.70E+07	1.08E+08	1.08E+08	1.08E+08
20	Residential (pervious)	2.55E+09	2.55E+09	2.55E+09	2.54E+09	2.54E+09	2.54E+09	2.54E+09	2.54E+09	2.54E+09	2.55E+09	2.55E+09	2.55E+09
20	Transitional (pervious)	1.64E+08	1.64E+08	1.64E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.64E+08	1.64E+08	1.64E+08
20	Cropland	1.79E+08	1.79E+08	1.79E+08	1.65E+08	1.65E+08	1.65E+08	1.65E+08	1.65E+08	1.65E+08	1.79E+08	1.79E+08	1.79E+08
20	Pasture	1.67E+10	1.67E+10	1.67E+10	1.67E+10	1.67E+10	1.67E+10	1.67E+10	1.67E+10	1.67E+10	1.67E+10	1.67E+10	1.67E+10
20	Degraded Riparian Pasture	1.67E+10	1.67E+10	1.67E+10	1.67E+10	1.67E+10	1.67E+10	1.67E+10	1.67E+10	1.67E+10	1.67E+10	1.67E+10	1.67E+10
20	Forest	1.79E+08	1.79E+08	1.79E+08	1.65E+08	1.65E+08	1.65E+08	1.65E+08	1.65E+08	1.65E+08	1.79E+08	1.79E+08	1.79E+08
20	Urban/Transportation (impervious)	1.64E+08	1.64E+08	1.64E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.64E+08	1.64E+08	1.64E+08
20	Residential (impervious)	2.55E+09	2.55E+09	2.55E+09	2.54E+09	2.54E+09	2.54E+09	2.54E+09	2.54E+09	2.54E+09	2.55E+09	2.55E+09	2.55E+09
20	Transitional (impervious)	1.64E+08	1.64E+08	1.64E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.64E+08	1.64E+08	1.64E+08

Table B-3. Monthly Maximum Storage (SQOLIM) Table for Fecal Coliform Loading to Spout Run Watershed Under Existing Conditions (cfu/acre).

Sub-watershed	Landuse	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Residential (pervious)	4.70E+09	4.70E+09	4.70E+09	3.89E+09	3.89E+09	3.89E+09	3.89E+09	3.89E+09	3.89E+09	4.70E+09	4.70E+09	4.70E+09
1	Transitional (pervious)	1.72E+08	1.72E+08	1.72E+08	1.11E+08	1.11E+08	1.11E+08	1.11E+08	1.11E+08	1.11E+08	1.72E+08	1.72E+08	1.72E+08
1	Cropland	1.81E+08	1.81E+08	1.81E+08	1.18E+08	1.18E+08	1.18E+08	1.18E+08	1.18E+08	1.18E+08	1.81E+08	1.81E+08	1.81E+08
1	Pasture	2.92E+10	2.92E+10	2.92E+10	2.43E+10	2.43E+10	2.43E+10	2.43E+10	2.43E+10	2.43E+10	2.92E+10	2.92E+10	2.92E+10
1	Degraded Riparian Pasture	2.92E+10	2.92E+10	2.92E+10	2.43E+10	2.43E+10	2.43E+10	2.43E+10	2.43E+10	2.43E+10	2.92E+10	2.92E+10	2.92E+10
1	Forest	1.81E+08	1.81E+08	1.81E+08	1.18E+08	1.18E+08	1.18E+08	1.18E+08	1.18E+08	1.18E+08	1.81E+08	1.81E+08	1.81E+08
1	Urban/Transportation (impervious)	1.71E+08	1.71E+08	1.71E+08	1.09E+08	1.09E+08	1.09E+08	1.09E+08	1.09E+08	1.09E+08	1.71E+08	1.71E+08	1.71E+08
1	Residential (impervious)	4.70E+09	4.70E+09	4.70E+09	3.89E+09	3.89E+09	3.89E+09	3.89E+09	3.89E+09	3.89E+09	4.70E+09	4.70E+09	4.70E+09
1	Transitional (impervious)	1.72E+08	1.72E+08	1.72E+08	1.11E+08	1.11E+08	1.11E+08	1.11E+08	1.11E+08	1.11E+08	1.72E+08	1.72E+08	1.72E+08
2	Residential (pervious)	9.15E+09	9.15E+09	9.15E+09	7.59E+09	7.59E+09	7.59E+09	7.59E+09	7.59E+09	7.59E+09	9.15E+09	9.15E+09	9.15E+09

2	Transitional (pervious)	2.02E+08	2.02E+08	2.02E+08	1.33E+08	1.33E+08	1.33E+08	1.33E+08	1.33E+08	1.33E+08	2.02E+08	2.02E+08	2.02E+08
2	Cropland	2.04E+08	2.04E+08	2.04E+08	4.09E+08	1.16E+09	2.31E+09	3.12E+09	1.56E+09	1.65E+09	1.27E+09	3.11E+09	9.66E+08
2	Pasture	2.90E+10	2.90E+10	2.90E+10	2.41E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.90E+10	2.91E+10	2.90E+10
2	Degraded Riparian Pasture	2.90E+10	2.90E+10	2.90E+10	2.41E+10	2.41E+10	2.41E+10	2.41E+10	2.41E+10	2.41E+10	2.90E+10	2.90E+10	2.90E+10
2	Forest	2.04E+08	2.04E+08	2.04E+08	1.35E+08	1.35E+08	1.35E+08	1.35E+08	1.35E+08	1.35E+08	2.04E+08	2.04E+08	2.04E+08
2	Urban/Transportation (impervious)	2.01E+08	2.01E+08	2.01E+08	1.32E+08	1.32E+08	1.32E+08	1.32E+08	1.32E+08	1.32E+08	2.01E+08	2.01E+08	2.01E+08
2	Residential (impervious)	9.15E+09	9.15E+09	9.15E+09	7.59E+09	7.59E+09	7.59E+09	7.59E+09	7.59E+09	7.59E+09	9.15E+09	9.15E+09	9.15E+09
2	Transitional (impervious)	2.02E+08	2.02E+08	2.02E+08	1.33E+08	1.33E+08	1.33E+08	1.33E+08	1.33E+08	1.33E+08	2.02E+08	2.02E+08	2.02E+08
3	Residential (pervious)	1.36E+09	1.36E+09	1.36E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.36E+09	1.36E+09	1.36E+09
3	Transitional (pervious)	1.76E+08	1.76E+08	1.76E+08	1.17E+08	1.17E+08	1.17E+08	1.17E+08	1.17E+08	1.17E+08	1.76E+08	1.76E+08	1.76E+08
3	Cropland	1.81E+08	1.81E+08	1.81E+08	2.10E+08	4.49E+08	8.18E+08	1.08E+09	5.78E+08	6.06E+08	5.22E+08	1.11E+09	4.25E+08
3	Pasture	2.93E+10	2.93E+10	2.93E+10	2.44E+10	2.45E+10	2.46E+10	2.47E+10	2.45E+10	2.45E+10	2.94E+10	2.96E+10	2.94E+10
3	Degraded Riparian Pasture	2.93E+10	2.93E+10	2.93E+10	2.44E+10	2.44E+10	2.44E+10	2.44E+10	2.44E+10	2.44E+10	2.93E+10	2.93E+10	2.93E+10
3	Forest	1.81E+08	1.81E+08	1.81E+08	1.21E+08	1.21E+08	1.21E+08	1.21E+08	1.21E+08	1.21E+08	1.81E+08	1.81E+08	1.81E+08
3	Urban/Transportation (impervious)	1.74E+08	1.74E+08	1.74E+08	1.16E+08	1.16E+08	1.16E+08	1.16E+08	1.16E+08	1.16E+08	1.74E+08	1.74E+08	1.74E+08
3	Residential (impervious)	1.36E+09	1.36E+09	1.36E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.36E+09	1.36E+09	1.36E+09
3	Transitional (impervious)	1.76E+08	1.76E+08	1.76E+08	1.17E+08	1.17E+08	1.17E+08	1.17E+08	1.17E+08	1.17E+08	1.76E+08	1.76E+08	1.76E+08
4	Residential (pervious)	4.63E+09	4.63E+09	4.63E+09	3.83E+09	3.83E+09	3.83E+09	3.83E+09	3.83E+09	3.83E+09	4.63E+09	4.63E+09	4.63E+09
4	Transitional (pervious)	1.56E+08	1.56E+08	1.56E+08	1.04E+08	1.04E+08	1.04E+08	1.04E+08	1.04E+08	1.04E+08	1.56E+08	1.56E+08	1.56E+08
4	Cropland	1.57E+08	1.57E+08	1.57E+08	1.70E+08	3.45E+08	6.14E+08	8.03E+08	4.38E+08	4.59E+08	4.06E+08	8.38E+08	3.35E+08
4	Pasture	5.11E+10	5.11E+10	5.11E+10	4.26E+10	4.27E+10	4.27E+10	4.28E+10	4.27E+10	4.27E+10	5.12E+10	5.13E+10	5.12E+10
4	Degraded Riparian Pasture	5.11E+10	5.11E+10	5.11E+10	4.26E+10	4.26E+10	4.26E+10	4.26E+10	4.26E+10	4.26E+10	5.11E+10	5.11E+10	5.11E+10
4	Forest	1.57E+08	1.57E+08	1.57E+08	1.05E+08	1.05E+08	1.05E+08	1.05E+08	1.05E+08	1.05E+08	1.57E+08	1.57E+08	1.57E+08
4	Urban/Transportation (impervious)	1.54E+08	1.54E+08	1.54E+08	1.03E+08	1.03E+08	1.03E+08	1.03E+08	1.03E+08	1.03E+08	1.54E+08	1.54E+08	1.54E+08
4	Residential (impervious)	4.63E+09	4.63E+09	4.63E+09	3.83E+09	3.83E+09	3.83E+09	3.83E+09	3.83E+09	3.83E+09	4.63E+09	4.63E+09	4.63E+09
4	Transitional (impervious)	1.56E+08	1.56E+08	1.56E+08	1.04E+08	1.04E+08	1.04E+08	1.04E+08	1.04E+08	1.04E+08	1.56E+08	1.56E+08	1.56E+08
5	Residential (pervious)	3.23E+09	3.23E+09	3.23E+09	2.68E+09	2.68E+09	2.68E+09	2.68E+09	2.68E+09	2.68E+09	3.23E+09	3.23E+09	3.23E+09
5	Transitional (pervious)	1.02E+08	1.02E+08	1.02E+08	7.40E+07	7.40E+07	7.40E+07	7.40E+07	7.40E+07	7.40E+07	1.02E+08	1.02E+08	1.02E+08
5	Cropland	1.04E+08	1.04E+08	1.04E+08	1.29E+08	2.75E+08	4.99E+08	6.57E+08	3.53E+08	3.70E+08	3.11E+08	6.71E+08	2.52E+08
5	Pasture	2.91E+10	2.91E+10	2.91E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.91E+10	2.91E+10	2.91E+10
5	Degraded Riparian Pasture	2.91E+10	2.91E+10	2.91E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.91E+10	2.91E+10	2.91E+10
5	Forest	1.04E+08	1.04E+08	1.04E+08	7.51E+07	7.51E+07	7.51E+07	7.51E+07	7.51E+07	7.51E+07	1.04E+08	1.04E+08	1.04E+08
5	Urban/Transportation (impervious)	1.01E+08	1.01E+08	1.01E+08	7.26E+07	7.26E+07	7.26E+07	7.26E+07	7.26E+07	7.26E+07	1.01E+08	1.01E+08	1.01E+08

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5	Residential (impervious)	3.23E+09	3.23E+09	3.23E+09	2.68E+09	2.68E+09	2.68E+09	2.68E+09	2.68E+09	2.68E+09	3.23E+09	3.23E+09	3.23E+09
5	Transitional (impervious)	1.02E+08	1.02E+08	1.02E+08	7.40E+07	7.40E+07	7.40E+07	7.40E+07	7.40E+07	7.40E+07	1.02E+08	1.02E+08	1.02E+08
6	Residential (pervious)	1.42E+09	1.42E+09	1.42E+09	1.15E+09	1.15E+09	1.15E+09	1.15E+09	1.15E+09	1.15E+09	1.42E+09	1.42E+09	1.42E+09
6	Transitional (pervious)	1.53E+08	1.53E+08	1.53E+08	9.91E+07	9.91E+07	9.91E+07	9.91E+07	9.91E+07	9.91E+07	1.53E+08	1.53E+08	1.53E+08
6	Cropland	1.68E+08	1.68E+08	1.68E+08	1.12E+08	1.12E+08	1.12E+08	1.12E+08	1.12E+08	1.12E+08	1.68E+08	1.68E+08	1.68E+08
6	Pasture	2.88E+10	2.88E+10	2.88E+10	2.39E+10	2.39E+10	2.38E+10	2.38E+10	2.38E+10	2.39E+10	2.88E+10	2.88E+10	2.88E+10
6	Degraded Riparian Pasture	2.88E+10	2.88E+10	2.88E+10	2.39E+10	2.39E+10	2.38E+10	2.38E+10	2.38E+10	2.39E+10	2.88E+10	2.88E+10	2.88E+10
6	Forest	1.68E+08	1.68E+08	1.68E+08	1.12E+08	1.12E+08	1.12E+08	1.12E+08	1.12E+08	1.12E+08	1.68E+08	1.68E+08	1.68E+08
6	Urban/Transportation (impervious)	1.51E+08	1.51E+08	1.51E+08	9.78E+07	9.78E+07	9.78E+07	9.78E+07	9.78E+07	9.78E+07	1.51E+08	1.51E+08	1.51E+08
6	Residential (impervious)	1.42E+09	1.42E+09	1.42E+09	1.15E+09	1.15E+09	1.15E+09	1.15E+09	1.15E+09	1.15E+09	1.42E+09	1.42E+09	1.42E+09
6	Transitional (impervious)	1.53E+08	1.53E+08	1.53E+08	9.91E+07	9.91E+07	9.91E+07	9.91E+07	9.91E+07	9.91E+07	1.53E+08	1.53E+08	1.53E+08
7	Residential (pervious)	5.25E+09	5.25E+09	5.25E+09	4.35E+09	4.35E+09	4.35E+09	4.35E+09	4.35E+09	4.35E+09	5.25E+09	5.25E+09	5.25E+09
7	Transitional (pervious)	1.61E+08	1.61E+08	1.61E+08	1.08E+08	1.08E+08	1.08E+08	1.08E+08	1.08E+08	1.08E+08	1.61E+08	1.61E+08	1.61E+08
7	Cropland	1.64E+08	1.64E+08	1.64E+08	6.07E+10	6.09E+10	8.09E+08	1.07E+09	5.68E+08	5.96E+08	5.06E+08	1.10E+09	4.09E+08
7	Pasture	2.91E+10	2.91E+10	2.91E+10	2.69E+10	2.69E+10	2.43E+10	2.44E+10	2.43E+10	2.43E+10	2.91E+10	2.92E+10	2.91E+10
7	Degraded Riparian Pasture	2.91E+10	2.91E+10	2.91E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.91E+10	2.91E+10	2.91E+10
7	Forest	1.64E+08	1.64E+08	1.64E+08	1.11E+08	1.11E+08	1.11E+08	1.11E+08	1.11E+08	1.11E+08	1.64E+08	1.64E+08	1.64E+08
7	Urban/Transportation (impervious)	1.59E+08	1.59E+08	1.59E+08	1.07E+08	1.07E+08	1.07E+08	1.07E+08	1.07E+08	1.07E+08	1.59E+08	1.59E+08	1.59E+08
7	Residential (impervious)	5.25E+09	5.25E+09	5.25E+09	4.35E+09	4.35E+09	4.35E+09	4.35E+09	4.35E+09	4.35E+09	5.25E+09	5.25E+09	5.25E+09
7	Transitional (impervious)	1.61E+08	1.61E+08	1.61E+08	1.08E+08	1.08E+08	1.08E+08	1.08E+08	1.08E+08	1.08E+08	1.61E+08	1.61E+08	1.61E+08
8	Residential (pervious)	2.25E+09	2.25E+09	2.25E+09	1.84E+09	1.84E+09	1.84E+09	1.84E+09	1.84E+09	1.84E+09	2.25E+09	2.25E+09	2.25E+09
8	Transitional (pervious)	2.16E+08	2.16E+08	2.16E+08	1.42E+08	1.42E+08	1.42E+08	1.42E+08	1.42E+08	1.42E+08	2.16E+08	2.16E+08	2.16E+08
8	Cropland	2.26E+08	2.26E+08	2.26E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	2.26E+08	2.26E+08	2.26E+08
8	Pasture	2.75E+10	2.75E+10	2.75E+10	2.29E+10	2.29E+10	2.29E+10	2.29E+10	2.29E+10	2.29E+10	2.75E+10	2.75E+10	2.75E+10
8	Degraded Riparian Pasture	2.75E+10	2.75E+10	2.75E+10	2.29E+10	2.29E+10	2.29E+10	2.29E+10	2.29E+10	2.29E+10	2.75E+10	2.75E+10	2.75E+10
8	Forest	2.26E+08	2.26E+08	2.26E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	2.26E+08	2.26E+08	2.26E+08
8	Urban/Transportation (impervious)	2.15E+08	2.15E+08	2.15E+08	1.41E+08	1.41E+08	1.41E+08	1.41E+08	1.41E+08	1.41E+08	2.15E+08	2.15E+08	2.15E+08
8	Residential (impervious)	2.25E+09	2.25E+09	2.25E+09	1.84E+09	1.84E+09	1.84E+09	1.84E+09	1.84E+09	1.84E+09	2.25E+09	2.25E+09	2.25E+09
8	Transitional (impervious)	2.16E+08	2.16E+08	2.16E+08	1.42E+08	1.42E+08	1.42E+08	1.42E+08	1.42E+08	1.42E+08	2.16E+08	2.16E+08	2.16E+08
9	Residential (pervious)	1.39E+09	1.39E+09	1.39E+09	1.14E+09	1.14E+09	1.14E+09	1.14E+09	1.14E+09	1.14E+09	1.39E+09	1.39E+09	1.39E+09
9	Transitional (pervious)	1.63E+08	1.63E+08	1.63E+08	1.11E+08	1.11E+08	1.11E+08	1.11E+08	1.11E+08	1.11E+08	1.63E+08	1.63E+08	1.63E+08
9	Cropland	1.66E+08	1.66E+08	1.66E+08	2.20E+08	5.09E+08	9.54E+08	1.27E+09	6.64E+08	6.98E+08	5.78E+08	1.29E+09	4.61E+08
9	Pasture	2.90E+10	2.90E+10	2.90E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.91E+10	2.91E+10	2.91E+10
9	Degraded Riparian Pasture	2.90E+10	2.90E+10	2.90E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.90E+10	2.90E+10	2.90E+10

9	Forest	1.66E+08	1.66E+08	1.66E+08	1.13E+08	1.13E+08	1.13E+08	1.13E+08	1.13E+08	1.13E+08	1.66E+08	1.66E+08	1.66E+08
9	Urban/Transportation (impervious)	1.61E+08	1.61E+08	1.61E+08	1.09E+08	1.09E+08	1.09E+08	1.09E+08	1.09E+08	1.09E+08	1.61E+08	1.61E+08	1.61E+08
9	Residential (impervious)	1.39E+09	1.39E+09	1.39E+09	1.14E+09	1.14E+09	1.14E+09	1.14E+09	1.14E+09	1.14E+09	1.39E+09	1.39E+09	1.39E+09
9	Transitional (impervious)	1.63E+08	1.63E+08	1.63E+08	1.11E+08	1.11E+08	1.11E+08	1.11E+08	1.11E+08	1.11E+08	1.63E+08	1.63E+08	1.63E+08
10	Residential (pervious)	1.49E+09	1.49E+09	1.49E+09	1.20E+09	1.20E+09	1.20E+09	1.20E+09	1.20E+09	1.20E+09	1.49E+09	1.49E+09	1.49E+09
10	Transitional (pervious)	2.25E+08	2.25E+08	2.25E+08	1.48E+08	1.48E+08	1.48E+08	1.48E+08	1.48E+08	1.48E+08	2.25E+08	2.25E+08	2.25E+08
10	Cropland	2.30E+08	2.30E+08	2.30E+08	6.07E+10	6.08E+10	6.63E+08	8.53E+08	4.87E+08	5.07E+08	4.80E+08	9.14E+08	4.09E+08
10	Pasture	2.91E+10	2.91E+10	2.91E+10	2.61E+10	2.61E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.91E+10	2.91E+10	2.91E+10
10	Degraded Riparian Pasture	2.91E+10	2.91E+10	2.91E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.91E+10	2.91E+10	2.91E+10
10	Forest	2.30E+08	2.30E+08	2.30E+08	1.52E+08	1.52E+08	1.52E+08	1.52E+08	1.52E+08	1.52E+08	2.30E+08	2.30E+08	2.30E+08
10	Urban/Transportation (impervious)	2.23E+08	2.23E+08	2.23E+08	1.46E+08	1.46E+08	1.46E+08	1.46E+08	1.46E+08	1.46E+08	2.23E+08	2.23E+08	2.23E+08
10	Residential (impervious)	1.49E+09	1.49E+09	1.49E+09	1.20E+09	1.20E+09	1.20E+09	1.20E+09	1.20E+09	1.20E+09	1.49E+09	1.49E+09	1.49E+09
10	Transitional (impervious)	2.25E+08	2.25E+08	2.25E+08	1.48E+08	1.48E+08	1.48E+08	1.48E+08	1.48E+08	1.48E+08	2.25E+08	2.25E+08	2.25E+08
11	Residential (pervious)	2.34E+09	2.34E+09	2.34E+09	1.91E+09	1.91E+09	1.91E+09	1.91E+09	1.91E+09	1.91E+09	2.34E+09	2.34E+09	2.34E+09
11	Transitional (pervious)	2.03E+08	2.03E+08	2.03E+08	1.31E+08	1.31E+08	1.31E+08	1.31E+08	1.31E+08	1.31E+08	2.03E+08	2.03E+08	2.03E+08
11	Cropland	2.07E+08	2.07E+08	2.07E+08	6.06E+10	6.07E+10	3.03E+08	3.67E+08	2.45E+08	2.52E+08	2.90E+08	4.34E+08	2.66E+08
11	Pasture	2.89E+10	2.89E+10	2.89E+10	3.88E+10	3.88E+10	2.41E+10	2.41E+10	2.41E+10	2.41E+10	2.89E+10	2.89E+10	2.89E+10
11	Degraded Riparian Pasture	2.89E+10	2.89E+10	2.89E+10	2.41E+10	2.41E+10	2.41E+10	2.41E+10	2.41E+10	2.41E+10	2.89E+10	2.89E+10	2.89E+10
11	Forest	2.07E+08	2.07E+08	2.07E+08	1.34E+08	1.34E+08	1.34E+08	1.34E+08	1.34E+08	1.34E+08	2.07E+08	2.07E+08	2.07E+08
11	Urban/Transportation (impervious)	2.02E+08	2.02E+08	2.02E+08	1.30E+08	1.30E+08	1.30E+08	1.30E+08	1.30E+08	1.30E+08	2.02E+08	2.02E+08	2.02E+08
11	Residential (impervious)	2.34E+09	2.34E+09	2.34E+09	1.91E+09	1.91E+09	1.91E+09	1.91E+09	1.91E+09	1.91E+09	2.34E+09	2.34E+09	2.34E+09
11	Transitional (impervious)	2.03E+08	2.03E+08	2.03E+08	1.31E+08	1.31E+08	1.31E+08	1.31E+08	1.31E+08	1.31E+08	2.03E+08	2.03E+08	2.03E+08
12	Residential (pervious)	2.92E+08	2.92E+08	2.92E+08	2.23E+08	2.23E+08	2.23E+08	2.23E+08	2.23E+08	2.23E+08	2.92E+08	2.92E+08	2.92E+08
12	Transitional (pervious)	2.95E+08	2.95E+08	2.95E+08	2.25E+08	2.25E+08	2.25E+08	2.25E+08	2.25E+08	2.25E+08	2.95E+08	2.95E+08	2.95E+08
12	Cropland	3.09E+08	3.09E+08	3.09E+08	2.37E+08	2.37E+08	2.37E+08	2.37E+08	2.37E+08	2.37E+08	3.09E+08	3.09E+08	3.09E+08
12	Pasture	2.89E+10	2.89E+10	2.89E+10	2.40E+10	2.40E+10	2.39E+10	2.39E+10	2.39E+10	2.40E+10	2.89E+10	2.89E+10	2.89E+10
12	Degraded Riparian Pasture	2.89E+10	2.89E+10	2.89E+10	2.40E+10	2.40E+10	2.39E+10	2.39E+10	2.39E+10	2.40E+10	2.89E+10	2.89E+10	2.89E+10
12	Forest	3.09E+08	3.09E+08	3.09E+08	2.37E+08	2.37E+08	2.37E+08	2.37E+08	2.37E+08	2.37E+08	3.09E+08	3.09E+08	3.09E+08
12	Urban/Transportation (impervious)	2.92E+08	2.92E+08	2.92E+08	2.23E+08	2.23E+08	2.23E+08	2.23E+08	2.23E+08	2.23E+08	2.92E+08	2.92E+08	2.92E+08
12	Residential (impervious)	2.92E+08	2.92E+08	2.92E+08	2.23E+08	2.23E+08	2.23E+08	2.23E+08	2.23E+08	2.23E+08	2.92E+08	2.92E+08	2.92E+08
12	Transitional (impervious)	2.95E+08	2.95E+08	2.95E+08	2.25E+08	2.25E+08	2.25E+08	2.25E+08	2.25E+08	2.25E+08	2.95E+08	2.95E+08	2.95E+08
13	Residential (pervious)	1.49E+09	1.49E+09	1.49E+09	1.23E+09	1.23E+09	1.23E+09	1.23E+09	1.23E+09	1.23E+09	1.49E+09	1.49E+09	1.49E+09
13	Transitional (pervious)	9.97E+07	9.97E+07	9.97E+07	7.35E+07	7.35E+07	7.35E+07	7.35E+07	7.35E+07	7.35E+07	9.97E+07	9.97E+07	9.97E+07

13	Cropland	1.03E+08	1.03E+08	1.03E+08	7.62E+07	7.62E+07	7.62E+07	7.62E+07	7.62E+07	7.62E+07	1.03E+08	1.03E+08	1.03E+08
13	Pasture	2.90E+10	2.90E+10	2.90E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.90E+10	2.90E+10	2.90E+10
13	Degraded Riparian Pasture	2.90E+10	2.90E+10	2.90E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.90E+10	2.90E+10	2.90E+10
13	Forest	1.03E+08	1.03E+08	1.03E+08	7.62E+07	7.62E+07	7.62E+07	7.62E+07	7.62E+07	7.62E+07	1.03E+08	1.03E+08	1.03E+08
13	Urban/Transportation (impervious)	9.79E+07	9.79E+07	9.79E+07	7.20E+07	7.20E+07	7.20E+07	7.20E+07	7.20E+07	7.20E+07	9.79E+07	9.79E+07	9.79E+07
13	Residential (impervious)	1.49E+09	1.49E+09	1.49E+09	1.23E+09	1.23E+09	1.23E+09	1.23E+09	1.23E+09	1.23E+09	1.49E+09	1.49E+09	1.49E+09
13	Transitional (impervious)	9.97E+07	9.97E+07	9.97E+07	7.35E+07	7.35E+07	7.35E+07	7.35E+07	7.35E+07	7.35E+07	9.97E+07	9.97E+07	9.97E+07
14	Residential (pervious)	6.99E+08	6.99E+08	6.99E+08	5.46E+08	5.46E+08	5.46E+08	5.46E+08	5.46E+08	5.46E+08	6.99E+08	6.99E+08	6.99E+08
14	Transitional (pervious)	2.02E+08	2.02E+08	2.02E+08	1.32E+08	1.32E+08	1.32E+08	1.32E+08	1.32E+08	1.32E+08	2.02E+08	2.02E+08	2.02E+08
14	Cropland	2.15E+08	2.15E+08	2.15E+08	1.42E+08	1.42E+08	1.42E+08	1.42E+08	1.42E+08	1.42E+08	2.15E+08	2.15E+08	2.15E+08
14	Pasture	2.95E+10	2.95E+10	2.95E+10	2.45E+10	2.45E+10	2.45E+10	2.45E+10	2.45E+10	2.45E+10	2.95E+10	2.95E+10	2.95E+10
14	Degraded Riparian Pasture	2.95E+10	2.95E+10	2.95E+10	2.45E+10	2.45E+10	2.45E+10	2.45E+10	2.45E+10	2.45E+10	2.95E+10	2.95E+10	2.95E+10
14	Forest	2.15E+08	2.15E+08	2.15E+08	1.42E+08	1.42E+08	1.42E+08	1.42E+08	1.42E+08	1.42E+08	2.15E+08	2.15E+08	2.15E+08
14	Urban/Transportation (impervious)	2.01E+08	2.01E+08	2.01E+08	1.31E+08	1.31E+08	1.31E+08	1.31E+08	1.31E+08	1.31E+08	2.01E+08	2.01E+08	2.01E+08
14	Residential (impervious)	6.99E+08	6.99E+08	6.99E+08	5.46E+08	5.46E+08	5.46E+08	5.46E+08	5.46E+08	5.46E+08	6.99E+08	6.99E+08	6.99E+08
14	Transitional (impervious)	2.02E+08	2.02E+08	2.02E+08	1.32E+08	1.32E+08	1.32E+08	1.32E+08	1.32E+08	1.32E+08	2.02E+08	2.02E+08	2.02E+08
15	Residential (pervious)	4.73E+09	4.73E+09	4.73E+09	3.93E+09	3.93E+09	3.93E+09	3.93E+09	3.93E+09	3.93E+09	4.73E+09	4.73E+09	4.73E+09
15	Transitional (pervious)	1.10E+08	1.10E+08	1.10E+08	7.88E+07	7.88E+07	7.88E+07	7.88E+07	7.88E+07	7.88E+07	1.10E+08	1.10E+08	1.10E+08
15	Cropland	1.16E+08	1.16E+08	1.16E+08	6.05E+10	6.05E+10	8.40E+07	8.40E+07	8.40E+07	8.40E+07	1.16E+08	1.16E+08	1.16E+08
15	Pasture	2.90E+10	2.90E+10	2.90E+10	2.49E+10	2.49E+10	2.41E+10	2.41E+10	2.41E+10	2.41E+10	2.90E+10	2.90E+10	2.90E+10
15	Degraded Riparian Pasture	2.90E+10	2.90E+10	2.90E+10	2.41E+10	2.41E+10	2.41E+10	2.41E+10	2.41E+10	2.41E+10	2.90E+10	2.90E+10	2.90E+10
15	Forest	1.16E+08	1.16E+08	1.16E+08	8.40E+07	8.40E+07	8.40E+07	8.40E+07	8.40E+07	8.40E+07	1.16E+08	1.16E+08	1.16E+08
15	Urban/Transportation (impervious)	1.08E+08	1.08E+08	1.08E+08	7.74E+07	7.74E+07	7.74E+07	7.74E+07	7.74E+07	7.74E+07	1.08E+08	1.08E+08	1.08E+08
15	Residential (impervious)	4.73E+09	4.73E+09	4.73E+09	3.93E+09	3.93E+09	3.93E+09	3.93E+09	3.93E+09	3.93E+09	4.73E+09	4.73E+09	4.73E+09
15	Transitional (impervious)	1.10E+08	1.10E+08	1.10E+08	7.88E+07	7.88E+07	7.88E+07	7.88E+07	7.88E+07	7.88E+07	1.10E+08	1.10E+08	1.10E+08
16	Residential (pervious)	1.53E+09	1.53E+09	1.53E+09	1.26E+09	1.26E+09	1.26E+09	1.26E+09	1.26E+09	1.26E+09	1.53E+09	1.53E+09	1.53E+09
16	Transitional (pervious)	1.32E+08	1.32E+08	1.32E+08	9.28E+07	9.28E+07	9.28E+07	9.28E+07	9.28E+07	9.28E+07	1.32E+08	1.32E+08	1.32E+08
16	Cropland	1.36E+08	1.36E+08	1.36E+08	7.86E+10	7.86E+10	2.97E+08	3.73E+08	2.28E+08	2.36E+08	3.23E+10	3.24E+10	2.06E+08
16	Pasture	2.90E+10	2.90E+10	2.90E+10	2.70E+10	2.70E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	3.36E+10	3.36E+10	2.90E+10
16	Degraded Riparian Pasture	2.90E+10	2.90E+10	2.90E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.90E+10	2.90E+10	2.90E+10
16	Forest	1.36E+08	1.36E+08	1.36E+08	9.61E+07	9.61E+07	9.61E+07	9.61E+07	9.61E+07	9.61E+07	1.36E+08	1.36E+08	1.36E+08
16	Urban/Transportation (impervious)	1.30E+08	1.30E+08	1.30E+08	9.15E+07	9.15E+07	9.15E+07	9.15E+07	9.15E+07	9.15E+07	1.30E+08	1.30E+08	1.30E+08
16	Residential (impervious)	1.53E+09	1.53E+09	1.53E+09	1.26E+09	1.26E+09	1.26E+09	1.26E+09	1.26E+09	1.26E+09	1.53E+09	1.53E+09	1.53E+09

16	Transitional (impervious)	1.32E+08	1.32E+08	1.32E+08	9.28E+07	9.28E+07	9.28E+07	9.28E+07	9.28E+07	9.28E+07	1.32E+08	1.32E+08	1.32E+08
17	Residential (pervious)	5.21E+09	5.21E+09	5.21E+09	4.32E+09	4.32E+09	4.32E+09	4.32E+09	4.32E+09	4.32E+09	5.21E+09	5.21E+09	5.21E+09
17	Transitional (pervious)	1.38E+08	1.38E+08	1.38E+08	9.66E+07	9.66E+07	9.66E+07	9.66E+07	9.66E+07	9.66E+07	1.38E+08	1.38E+08	1.38E+08
17	Cropland	1.43E+08	1.43E+08	1.43E+08	1.66E+08	3.45E+08	6.19E+08	8.13E+08	4.40E+08	4.61E+08	3.97E+08	8.37E+08	3.24E+08
17	Pasture	2.90E+10	2.90E+10	2.90E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.42E+10	2.90E+10	2.90E+10	2.90E+10
17	Degraded Riparian Pasture	2.90E+10	2.90E+10	2.90E+10	2.41E+10	2.41E+10	2.41E+10	2.41E+10	2.41E+10	2.41E+10	2.90E+10	2.90E+10	2.90E+10
17	Forest	1.43E+08	1.43E+08	1.43E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.43E+08	1.43E+08	1.43E+08
17	Urban/Transportation (impervious)	1.36E+08	1.36E+08	1.36E+08	9.52E+07	9.52E+07	9.52E+07	9.52E+07	9.52E+07	9.52E+07	1.36E+08	1.36E+08	1.36E+08
17	Residential (impervious)	5.21E+09	5.21E+09	5.21E+09	4.32E+09	4.32E+09	4.32E+09	4.32E+09	4.32E+09	4.32E+09	5.21E+09	5.21E+09	5.21E+09
17	Transitional (impervious)	1.38E+08	1.38E+08	1.38E+08	9.66E+07	9.66E+07	9.66E+07	9.66E+07	9.66E+07	9.66E+07	1.38E+08	1.38E+08	1.38E+08
18	Residential (pervious)	1.07E+10	1.07E+10	1.07E+10	8.86E+09	8.86E+09	8.86E+09	8.86E+09	8.86E+09	8.86E+09	1.07E+10	1.07E+10	1.07E+10
18	Transitional (pervious)	2.40E+08	2.40E+08	2.40E+08	1.46E+08	1.46E+08	1.46E+08	1.46E+08	1.46E+08	1.46E+08	2.40E+08	2.40E+08	2.40E+08
18	Cropland	2.64E+08	2.64E+08	2.64E+08	1.66E+08	1.66E+08	1.66E+08	1.66E+08	1.66E+08	1.66E+08	2.64E+08	2.64E+08	2.64E+08
18	Pasture	2.90E+10	2.90E+10	2.90E+10	2.41E+10	2.41E+10	2.41E+10	2.41E+10	2.41E+10	2.41E+10	2.90E+10	2.90E+10	2.90E+10
18	Degraded Riparian Pasture	2.90E+10	2.90E+10	2.90E+10	2.41E+10	2.41E+10	2.41E+10	2.41E+10	2.41E+10	2.41E+10	2.90E+10	2.90E+10	2.90E+10
18	Forest	2.64E+08	2.64E+08	2.64E+08	1.66E+08	1.66E+08	1.66E+08	1.66E+08	1.66E+08	1.66E+08	2.64E+08	2.64E+08	2.64E+08
18	Urban/Transportation (impervious)	2.39E+08	2.39E+08	2.39E+08	1.44E+08	1.44E+08	1.44E+08	1.44E+08	1.44E+08	1.44E+08	2.39E+08	2.39E+08	2.39E+08
18	Residential (impervious)	1.07E+10	1.07E+10	1.07E+10	8.86E+09	8.86E+09	8.86E+09	8.86E+09	8.86E+09	8.86E+09	1.07E+10	1.07E+10	1.07E+10
18	Transitional (impervious)	2.40E+08	2.40E+08	2.40E+08	1.46E+08	1.46E+08	1.46E+08	1.46E+08	1.46E+08	1.46E+08	2.40E+08	2.40E+08	2.40E+08
19	Residential (pervious)	1.44E+09	1.44E+09	1.44E+09	1.16E+09	1.16E+09	1.16E+09	1.16E+09	1.16E+09	1.16E+09	1.44E+09	1.44E+09	1.44E+09
19	Transitional (pervious)	1.94E+08	1.94E+08	1.94E+08	1.31E+08	1.31E+08	1.31E+08	1.31E+08	1.31E+08	1.31E+08	1.94E+08	1.94E+08	1.94E+08
19	Cropland	2.01E+08	2.01E+08	2.01E+08	1.36E+08	1.36E+08	1.36E+08	1.36E+08	1.36E+08	1.36E+08	2.01E+08	2.01E+08	2.01E+08
19	Pasture	3.08E+10	3.08E+10	3.08E+10	2.56E+10	2.56E+10	2.56E+10	2.56E+10	2.56E+10	2.56E+10	3.08E+10	3.08E+10	3.08E+10
19	Degraded Riparian Pasture	3.08E+10	3.08E+10	3.08E+10	2.56E+10	2.56E+10	2.56E+10	2.56E+10	2.56E+10	2.56E+10	3.08E+10	3.08E+10	3.08E+10
19	Forest	2.01E+08	2.01E+08	2.01E+08	1.36E+08	1.36E+08	1.36E+08	1.36E+08	1.36E+08	1.36E+08	2.01E+08	2.01E+08	2.01E+08
19	Urban/Transportation (impervious)	1.92E+08	1.92E+08	1.92E+08	1.29E+08	1.29E+08	1.29E+08	1.29E+08	1.29E+08	1.29E+08	1.92E+08	1.92E+08	1.92E+08
19	Residential (impervious)	1.44E+09	1.44E+09	1.44E+09	1.16E+09	1.16E+09	1.16E+09	1.16E+09	1.16E+09	1.16E+09	1.44E+09	1.44E+09	1.44E+09
19	Transitional (impervious)	1.94E+08	1.94E+08	1.94E+08	1.31E+08	1.31E+08	1.31E+08	1.31E+08	1.31E+08	1.31E+08	1.94E+08	1.94E+08	1.94E+08
20	Residential (pervious)	4.60E+09	4.60E+09	4.60E+09	3.81E+09	3.81E+09	3.81E+09	3.81E+09	3.81E+09	3.81E+09	4.60E+09	4.60E+09	4.60E+09
20	Transitional (pervious)	2.96E+08	2.96E+08	2.96E+08	2.25E+08	2.25E+08	2.25E+08	2.25E+08	2.25E+08	2.25E+08	2.96E+08	2.96E+08	2.96E+08
20	Cropland	3.23E+08	3.23E+08	3.23E+08	2.48E+08	2.48E+08	2.48E+08	2.48E+08	2.48E+08	2.48E+08	3.23E+08	3.23E+08	3.23E+08
20	Pasture	3.01E+10	3.01E+10	3.01E+10	2.51E+10	2.51E+10	2.51E+10	2.51E+10	2.51E+10	2.51E+10	3.01E+10	3.01E+10	3.01E+10
20	Degraded Riparian Pasture	3.01E+10	3.01E+10	3.01E+10	2.51E+10	2.51E+10	2.51E+10	2.51E+10	2.51E+10	2.51E+10	3.01E+10	3.01E+10	3.01E+10
20	Forest	3.23E+08	3.23E+08	3.23E+08	2.48E+08	2.48E+08	2.48E+08	2.48E+08	2.48E+08	2.48E+08	3.23E+08	3.23E+08	3.23E+08

20	Urban/Transportation (impervious)	2.96E+08	2.96E+08	2.96E+08	2.25E+08	2.25E+08	2.25E+08	2.25E+08	2.25E+08	2.25E+08	2.96E+08	2.96E+08	2.96E+08
20	Residential (impervious)	4.60E+09	4.60E+09	4.60E+09	3.81E+09	3.81E+09	3.81E+09	3.81E+09	3.81E+09	3.81E+09	4.60E+09	4.60E+09	4.60E+09
20	Transitional (impervious)	2.96E+08	2.96E+08	2.96E+08	2.25E+08	2.25E+08	2.25E+08	2.25E+08	2.25E+08	2.25E+08	2.96E+08	2.96E+08	2.96E+08